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COCHIN

The Commercial Molluscs of India

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THE COMMERCIAL MOLLUSCS OF INDIA

Edited By
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AND DR. K. S. RAO

JANUARY, 1974
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
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PREFACE

India has very valuable marine molluscan resources which have been utilized for food and for various other purposes since very ancient times. The pearl oysters, edible oysters, mussels, clams, ark-shells, the chank (*Xancus pyrum*), squids and cuttle-fish support important fisheries in different areas of the Indian coasts. The identity, distribution and exploitation of the common molluscan resources of our seas were studied during the early part of this century. During the recent decades detailed investigations have been made on the systematics, biology and fisheries of a number of commercially important species of molluscs and we have a good deal of information about them. Much work remains to be done to get a comprehensive picture of the resources. The production potentials of culturing marine bivalves in our coastal waters are very high since the shellfishes feed on phytoplankton and detritus and grow rapidly making very efficient use of primary production.

This Bulletin has been brought out to present a consolidated account of the different species of molluscs which constitute the important fishery resources. The available information on the biology, distribution and fisheries of the different species has been compiled in this publication and suggestions have been made for the conservation and judicious exploitation of the resources. The urgent need for farming mussels, edible oysters, clams and pearl oysters and for conducting experiments to develop cultured pearls from the Indian pearl oyster has been rightly stressed.

Apart from some people inhabiting coastal areas, a large section of the population of our country is either unaware of the value of molluscs as nutritious food or is prejudiced against their use due to conservative food habits. It is necessary to popularize molluscan sea foods in India. There is good scope for exporting canned and frozen molluscan meat in appreciable quantities, since there is demand for them in other countries.

It is hoped that this Bulletin would be useful to scientific workers and all those interested in the commercially important molluscs of the seas around India and stimulate further work which will lead to better exploitation, utilization and conservation of molluscan resources.

I thank my colleagues who have written the different chapters and all those members of the staff who have assisted in the preparation of this Bulletin.

Cochin,
January, 1974.

Dr. R. V. NAIR
DIRECTOR
Central Marine Fisheries
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I INTRODUCTION

R. V. Nair

India has extensive molluscan resources along her coasts, in the numerous bays, brackish waters and estuaries and in the seas around the Sub-Continent, comprising of shell-fish belonging to different taxonomic groups, mussels, oysters, clams, pearl-oysters, window-pane oysters, ark-shells, whelks, chanks, cowries, squids and cuttlefish which have been exploited since time immemorial for food, pearls and shells utilized in several ways. The total marine molluscan production of India has been estimated to be 1,515 tonnes in the year 1968 and 769 tonnes in 1969 (C. M. F. R. I. 1969a, b). The figures include only the Cephalopod catches. Data not being available about the landings of mussels, oysters, clams and many other molluscan shell-fish which are fished in appreciable quantities, we do not have accurate information about the total marine molluscan production of the country. The average annual total world marine molluscan production during the period 1964–1969 was 2·959 million tonnes (F. A. O., 1970a) and the production in 1969 was 3·10 million tonnes. As compared to several other countries India's landings of marine molluscs are low even after accounting for the production of bivalves, chanks and others. There is however, great scope for increasing production through systematic scientific investigation of the resources and exploitation.

Studies on commercial marine molluscs of India date back to the end of the last century. Melvill and Abercrombie (1893) and Melvill (1893) identified and described littoral marine molluscs collected at Bombay. Nevill (1877) presented a list of the molluscs identified and preserved in the Indian Museum. The taxonomy of the Cephalopods of the Indian region present in the Indian Museum has been dealt with by Goodrich (1896), Massy (1916) and Adam(1939). Preston (1909, 1910, 1911, 1914, 1915, 1916), Newton and Smith (1912) and Annandale and Kemp (1916) have identified a number of commercially important molluscs of Indian coasts. Herdman's Reports to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Mannar (1903–1906) dealing with different aspects of pearl oysters and pearl oyster fisheries like systematics, morphology and life-history of pearl oysters, parasites, pests and predators of pearl oysters, pearl formation, location of pearl banks, their ecology and flora and fauna are most outstanding and valuable reference works on the subject.

Hornell studied the molluscan resources of Indian coasts carefully, especially those of the composite Madras State, and published a number of detailed accounts dealing with the habits, habitat, distribution, fisheries and utilization of several commercial molluscs. Some of his important publications are on the Sacred Chank *Turbinella* (*Xancus*) *pyrum* (Hornell, 1914), Pearl oyster fisheries of the Gulf of Mannar and Palk Bay (Hornell, 1916, 1922 a), the need for oyster-farming in India (Hornell, 1910 b), the window-pane oysters of Okhamandal (Hornell, 1909a, b), edible molluscs of Madras Presidency (Hornell, 1917), and on commercial molluscs in general, (1922b, 1949a, 1949b, 1949c, 1951). The works of Gravely (1941) and Satyamurthi (1952, 1956) are helpful in identifying many species of commercial molluscs. The morphology of the rock-oyster *Ostrea* (*Crassostrea*) *cucullata* has been described by Awati and Rai (1932) who have also given a synopsis of species of oysters of the Indian coasts and made observations on the breeding period, early development, pests and fisheries of *O.* (*C.*) *cuculiata*. Rai (1928, 1932) has given an account of the fisheries and utilization of molluscs on the northern parts of the west coast of India.

From the time of the establishment of the Central Marine Fisheries Research Institute in 1947, the molluscan resources of the country have been investigated by staff of the Institute and we have valuable information on the biology and fisheries of a number of species viz., the edible oyster *Crassostrea madrasensis* (Rao, 1951a, 1953, 1956, 1958, 1969; Rao and Nayar, 1956), the mussels *Mytilus* spp. (Jones, 1968), the clams *Katelysia opima*, (Rao, 1951b), *Meretrix casta* (Abraham, 1953; Durve, 1964c) and *Donax* spp. (Nayar, 1955; Algarswami 1966), the ark-shell *Anadara granosa* (Narasimham, 1969), cephalopods (Rao, 1954; Silas 1968, 1969) and the ecology of pearl banks (Mahadevan and Nayar, 1967). In the Fisheries Department of the Madras State and Zoological Research Laboratories of Bombay, Madras and Annamalai Universities also useful research work on the general biology and physiological aspects of commercial molluscs has been done. The Symposium on Mollusca held at Ernakulam by the Marine Biological Association of India in January, 1968 has focused attention on the biology and utilization of molluscan shell-fish in the Indian region.

India's molluscan resources are either exploited indiscriminately to the detriment of the stocks as in some regions or altogether neglected as in most other regions. The mussels, oysters and clams are fished in large quantities in some areas causing marked depletion of the populations. It is necessary to culture these shell-fish in order to avoid damage to natural stocks through over-fishing.

In this work a comprehensive account is given of our present knowledge about the species of commercial molluscs of Indian Seas, their relative importance, distribution, habits, biology, fisheries and utilization. The need for a thorough

study of the biology of the different commercial species of molluscs which have not received attention yet, a survey of the molluscan resources and taking up of investigations which have applied value such as experimental farming of bivalves and exploratory fishing to locate areas of abundance not known now is pointed out. The probable factors responsible for the variations in abundance of pearl oysters on the pearl banks off Tuticorin in different years and the possibility of doing pearl culture commercially if researches are carried out for inducing pearl formation in the Indian Pearl Oyster *Pinctada fucata* are discussed. The scope for establishment of profitable processing and shell-craft industries if certain edible molluscan shell-fish and other commercial species are harvested in quantities is indicated.

II EDIBLE BIVALVES: MUSSELS AND OYSTERS

K. Satyanarayana Rao

MUSSELS

Edible sea mussels belonging to the genus *Mytilus* are fished in quantities on some parts of the Indian coasts and are commercially important. They are bivalves approximately triangular in shape, with a shell pointed at the anterior end, a firm, horny periostracum, and anchoring byssus threads secreted by byssus glands present in the foot. The mussels attach themselves to rocks or other hard substratum by these threads. The mussel resources are rich on the south-western coast. When occurring in abundance they form thick carpet-like growths on rocks and concrete constructions like piers and wharves. Large beds of *Mytilus* colonise concrete and timber structures in ports and harbours. Two species of mussels are represented along our coasts, the green mussel, *Mytilus viridis* Linnaeus and the brown mussel, *Mytilus* sp. M*ytilus viridis* enjoys a wide distribution, occurring on both the east and west coasts and is fairly abundant at Cochin, Malabar and southern coast of Mysore. On the other hand, the brown mussel has a very restricted distribution extending from South of Quilon to Tirunelveli coast (Jones, 1950; Rao, 1958).

Taxonomy

Phylum Mollusca
Class Pelecypoda
Order Filibranchia
Sub-Order Mytilacea
Family Mytilidae
Genus *Mytilus*

The family Mytilidae has been included by Thiele (1931) in the order Anisomyaria based on the nature of the adductor muscles, the anterior adductor being very much reduced or more or less completely suppressed in members of the order. Pelseneer (1906) whose classification has been followed in this work has included *Mytilus* under the order Filibranchia comprising bivalves with gills formed of parallel, ventrally directed and reflected filaments with ciliary interfilamentar junctions. The sub-order Mytilacea including the genus *Mytilus*

comprises of bivalves in which the anterior adductor muscle is smaller than the posterior adductor muscle or even absent, non-vascular junctions connect the gill lamellae, aorta is single and the ramifications of the gonads usually extend into the mantle. In members of the family Mytilidae the shell is anteriorly narrow, inequilateral, the ligament is external, the true hinge is absent and the mantle has one point of union posteriorly separating the exhalent aperture from the rest of the pallial opening. In the genus *Mytilus* the umbo is terminal, the hinge does not have teeth but is denticulated and the ligament is linear (White, 1937).

Mytilus viridis Linnaeus

Synonyms

Mytilus viridis Linnaeus 1758
Mytilus viridis Linnaeus 1767
Mytilus smaragdinus Chemnitz 1785
Mytilus smaragdinus Reeve 1858
Mytilus smaragdinus Hornell 1917
Mytilus viridis Hornell 1922 b
Mytilus smaragadinus Rai 1932
Mytilus viridis Satyamurthi 1956

Common names

Malayalam - *Kallumalkai, Kadukka.*

Description

Shell large, elongate sub-trigonal with its anterior end pointed, arched and beak-like, dorsal margin of shell angularly convex in the middle, posterior margin broadly rounded, ventral margin slightly concave, valves strongly inflated particularly in the anterior part, surface of shell strongly decussately striated, ligament strong and elongated, shell surface covered by a firm, horny, bright green periostracum (Fig. 1 A). The mussel attaches itself to hard substratum by means of tough, thin, flexible byssus threads secreted by byssus glands present in the byssus cavity and the foot.

The body has the visceral mass, with two pairs of gills covered by a pair of mantle lobes which are united dorsally and free ventrally. The gonads extend into the lobes of the mantle. The mantle is cream coloured but during the period of sexual activity it becomes deep reddish orange in colour in females. The foot is much reduced, tongue-shaped and has a groove posteriorly which is used like a sucker to adhere firmly to substratum.

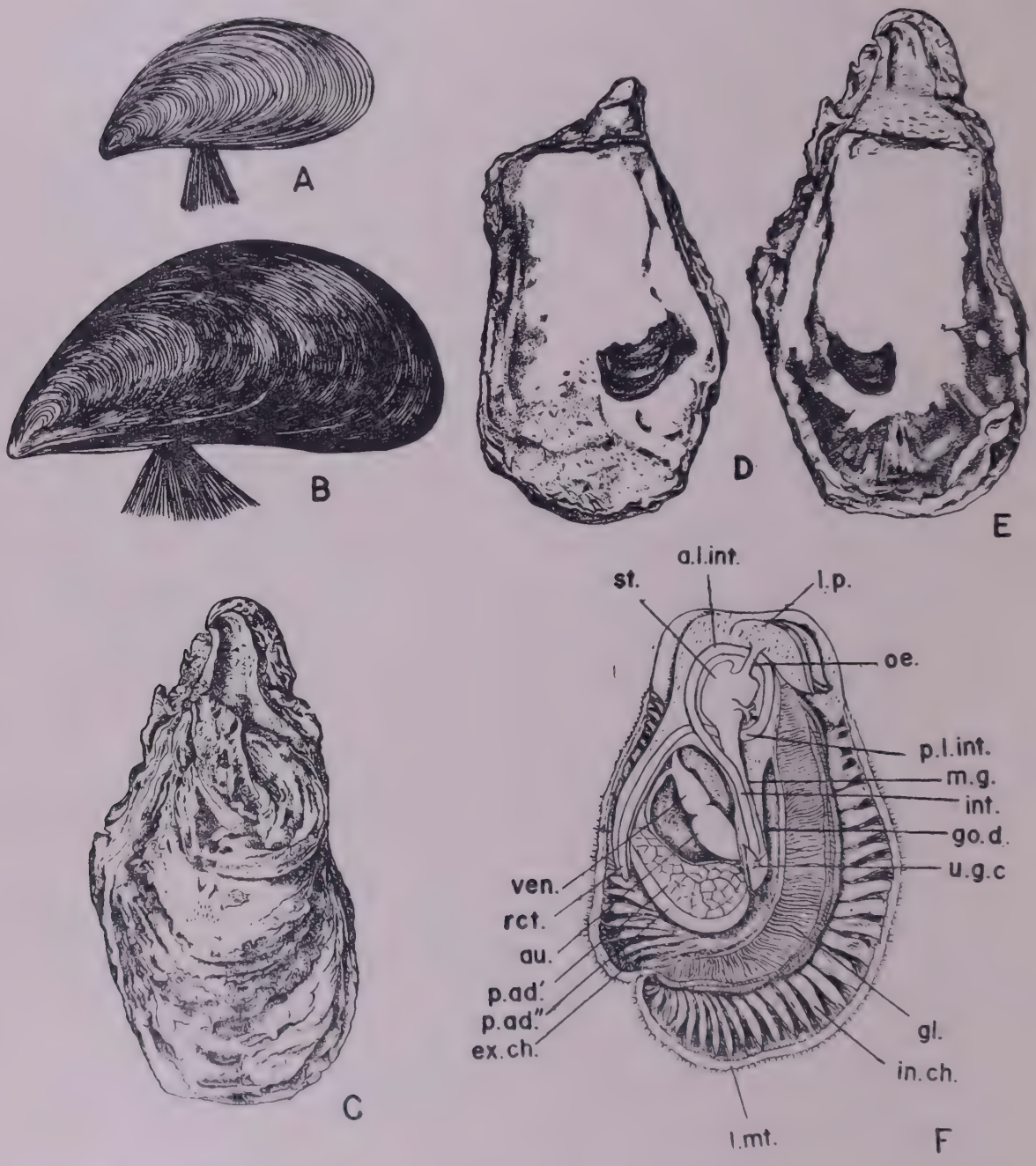

Fig. 1. A. *Mytilus viridis* Linnaeus. B. *Mytilus* sp. C. *Crassostrea madrasensis* (Preston). D and E. Internal view of right and left valves of *C. madrasensis*. F. Anatomy of *C. madrasensis* (Drawing by Mr. K. Virabhadra Rao). a.l.int., anterior loop of intestine; au., auricle; ex.ch., exhalent chamber; gl., gills; go.d., gonoduct; in.ch., inhalent chamber; int., intestine; l.mt., left mantle; l.p., labial palps; m.g., midgut; oe., oesophagus; p.ad'. anterior portion of adductor muscle; p.ad"., posterior portion of adductor muscle; p.l.int., posterior loop of intestine; rct. rectum; st., stomach; u.g.c., urinogenital cleft; ven., ventricle.

Distribution in India

The species occurs all along the east and west coasts of India. On the east coast it occurs generally as stragglers except in harbours. The mussels are abundant at Cochin, Malabar and north of Kerala. On the northern parts of the west coast it is found only in small numbers.

Habitat

In addition to open coasts and harbours the mussels are found in the mouths of estuaries and rivers as they are capable of withstanding wide variations of salinities. The mussels are found from low water mark to a depth of about three metres. They adhere firmly to the hard substratum by means of byssus threads and much effort is required to remove them.

Growth

The growth rate of *Mytilus viridis* is very rapid at Madras. Paul (1942) has recorded that *M. viridis* grows to 14.5 mm, 34.5 mm, 52 mm, 55.5 mm, 77.5 mm, and 103 mm in 30, 84, 164, 167, 241 and 445 days respectively in the Madras Harbour. Growth has been found to be continuous i.e., without interruption in any part of the year. Annual rings or growth checks which occur in bivalves due to cessation or slackening of growth in mussels of temperate seas have not been recorded in this species. Paul (1938) states that *M. viridis* probably attains the maximum size in two or three years. Field (1942) states that availablity of food organisms is the main factor determining the growth of mussels. He says that if food is scarce growth is retarded regardless of other conditions. Paul (1942) observed that growth was poor in mussels inhabiting isolated parts of the Madras Harbour where the inflow and outflow of sea water was restricted.

Reproduction

M. viriais attains maturity very quickly under tropical conditions at Madras. Forty eight day old female mussels 15.5 mm in length and 9.4 mm in breadth have been found to contain ripe eggs (Paul 1942). Spawning has been observed in 93 days old female. The European mussel *Mytilus edulis* becomes sexually mature only when about one year old (White, 1937). Mature individuals of *M. viridis* have been recorded from Madras harbour throughout the year and it has been stated that the species breeds all around the year (Paul, 1938; 1942). However, there is peak breeding activity from March or April to October. By contrast *Mytilus edulis* of British coasts has distinct periodicity spawning taking place twice in a year, between January and March and during July-August (Lebour, 1907. White 1937). Breeding in the tropical species *M. viridis* shows some similarity to that in *Mytilus californianus* off San Francisco with spawning all round the year (Whedon, 1936). But, in the American species peak spawning

begins in October and this is followed by two spawning seasons of smaller intensity in January-February and May-June. Whedon doubts whether changes in water temperature could induce spawning in mussels although they may play a part in the rate of development in early stages.

Spat

Spatfall takes place throughout the year in the Madras harbour with maximum density in the peak breeding period March-October (Paul, *loc. cit.*). Information is not available on the early growth of spat.

Food

The food and feeding habits of *Mytilus viridis* have not been studied in any detail. Field (1922) recorded as many as twenty nine species of diatoms and nine species of Protozoa in the stomachs of *M. edulis* but found that organic detritus formed half of the total amount of contents in the stomachs. It is considered that the detritus and smaller planktonic organisms are fed upon by the mussels and the rest is rejected as pseudofaeces.

Chemical composition

There is no information on the chemical composition of Indian mussels. Mussels are rich in protein and glycogen. In *M. edulis* of Great Britain protein forms 54.83%, glycogen 14.51%, lipid 8.06%, and salts 12.15% dry wt. (Daniel, 1923) and the glycogen level falls to a low level (5.95%) after spawning. Giese (1969) has recently investigated the organic constituents of the different parts of the body of *M. edulis* of Pacific coast of United States of America. The data reveal that the mantle and gonads of the mussels are richer than other body components in lipid (12.4 % dry wt.) while the foot has a high carbohydrate content (19.3 %). The seasonal changes in the chemical composition of the mussels should be studied to determine when the meats are in fit condition for consumption.

Fishery

The mussels are fished at Cochin, Malabar, Karwar, Ratnagiri, Bombay and Madras for eating. There is a good fishery for the green mussels from Varkalay near Quilon to the southern Mysore coast (Jones, 1968). the bivalves caught being found on the surface of rocks and man-made structures like piers and wharves. In Tellicherry there is an active fishery, 30 dug-out canoes being employed daily. On the south-western coast mussels are fished by dislodging hem with an iron chisel mounted on a wooden handle. Fishing is done between

9-10 a.m. and 2 p.m. Each boat in Tellichery lands 25-50 kg of mussels which are worth Rs. 6-12. They are sold in fresh condition in the markets at Re. 1 to Rs. 2. per hundred. Mussels are sold in markets at Calicut, Beypore, Cannanore Tellicherry and Mahe (Rao, 1958). At Bombay, Ratnagiri and Karwar the mussels are very much relished but they are rare there. At these centres mussels are fished only in fair sea seasons at low tide (Rai, 1932). Hornell (1922b) has stated that good quantities of green mussels occur in Sonapur backwaters but at present the mussels are sparse in the area and in Pulicat Lake. On the east coast the limited green mussel resources that exist are not fished intensively. No closed season is observed anywhere on the Indian coasts.

Mussel Culture

Mussel culture is not practised in India. There is good scope for culturing the green mussel in the numerous estuaries and backwaters of the country. Mussel culture is done on a large scale in western countries like Holland, France, Spain and England. There are two methods of mussel culture, the French or 'Buchot' method and the British method. The French method is stated (Field, 1908) to have been evolved as early as 1035 by an Irishman named Walton who was the sole survivor of a shipwreck in the Bay of Aiguillon. In this method V-shaped wooden enclosures the 'buchots' with the apex pointing out to the sea protecting the growing mussels from the vagaries of winds, waves and ice, are set up. A buchot consists of rows of stakes placed 60 cm apart and interlaced with a meshwork of flexible willow or chestnut branches 30-45 cm long and 5 cm in diameter. The stakes are trunks of trees, 3.6-4.5 metres in height and 15-30 cm. in diameter and driven into the ground to half their length. There are separate buchots for collecting spat and for fattening mussels. The buchots extend from high tide mark to deep water far away from the shore. Mussel spat settle on the buchots and grow and when about 5 months old they are transferred to buchots nearer shore where they are fastened in clusters with old netting. As the mussels attain larger and larger sizes, they are progressivly transferred some at a time to buchots nearer shore. When the mussels are 4-5 cm in size at the end of about one year they are kept on the stakes near the high tide level where they remain in good condition in spite of exposure twice a day. From there the mussels are taken whenever required for marketing. In the British method of culture which is comparatively very simple, young mussels are gathered from natural beds and transferred to estuaries or sheltered bays or backwaters where they are exposed part of the day at low tide and there is a good flow of water. The average yield from an acre of a mussel farm is estimated to be more than 100 tons. As the growth rate of the Indian mussels is very rapid and as they attain sexual maturity very quickly, in about three months time, culture of this species will be profitable if done with care on scientific lines.

MYTILUS SP.

This species is known as the brown mussel due to the predominant brown colour of the periostracum lining the shell. Its specific identity has not yet been established. This species grows to a length of about 11·8 cm. (4·6 inches) and is stouter than the green mussel.

COMMON NAMES

Malayalam — *Chippi, Muthuva, Muthu chippi*
Tamil — *Kallika, Kadal ka*

DESCRIPTION

Shell large, elongate sub-trigonal in shape with anterior end angular and pointed, dorsal margin angular, convex in the middle, posterior margin broadly rounded, ventral margin slightly concave, valves strongly inflated, especially in the anterior part, surface covered by a firm, horny, brown periostracum. The mussel attaches itself to substratum by well-developed byssus threads (Fig. 1 B).

DISTRIBUTION IN INDIA

From south of Quilon to Kanyakumari on west coast and along Tirunelveli coast.

HABITAT

Like the green mussel the brown mussel also is a sedentary bivalve living attached to rocks, piers and wharves. It has been recorded upto a depth of 6 metres. Complete submergence, clear water, availability of food and light, and presence of little suspended impurities are stated by Jones (1950) to be ideal conditions for this mussel. Mussels exposed to waves carrying sand or mud constantly get chocked up and die.

REPRODUCTION

Jones (*loc. cit.*) states that the breeding season of the mussel appears to be extended. The monsoon period June to August is the peak breeding period. In this period many rocks in the littoral region that are exposed in summer are submerged under the sea which becomes rough and moves shoreward in the rainy months. Clusters of young spat settle on the rocks over large areas. There is a second breeding peak in October and November but this is small in intensity as compared to the earlier one.

PESTS

Crabs of *Pinnotheres* sp. have been recorded inside brown mussels by Jones (1950). The crabs must be harmful to the well-being of the mussels by competing

for planktonic food organisms. The percentage of incidence of crabs in the mussels and whether the presence of the crabs affects the quality of the meat of the mussels should be studied. Algae and animals like hydroids, polyzoans, annelids and barnacles live attached to the surface of the shell of the mussels and are harmful to the mussels by weakening the shell, by polluting the water and by competing for food materials. The parasitic copepod *Mytilicola* occurs in mussels in Europe and America and causes significant damage (Quayle, 1969).

Fishery

There are important fishing centres between Kovalam near Trivandrum and Kanyakumari. The centres between Kovalam and Vizhinjam and those between Colachel and Muttom are the most important ones (Jones, 1968). Between Poovar and Kovalam mussel fishing is done by *pulayas* also known as *cherumas*. The mussel fishery extends from September to May or early June on south Travancore and Tirunelveli coasts. In September as the sea is calmer than in the preceding period carpet-like growths of *Mytilus* beds on rocks in the littoral region are exposed. Fishermen, women, children and old people gather the mussels from the rocks with hands, sometimes using a chisel mounted on a wooden handle. The regular fishing season begins in mid-November and continues till May. By the middle of November most of the mussels in the shoreward rocks having been fished, fishermen dive to submerged rocks in the subtidal zone and gather mussels present on them by dislodging with a chisel called 'uli'. The uli is a blunt edged knife 7.5 cm in width fixed on a softwood handle 45 cm. long and 3.8 cm. diameter. The mussels collected are put in a coir bag 45 cm. in length and 30 cm. in width. After diving as long as he can and collecting mussels the fisherman comes up and goes down after resting for sometime. Fishing is done between 9 or 10 a.m. and 2 p.m. To reach the seaward rocks the fishermen go in catamarans. A fisherman earns Rs. 4 to Rs. 8 per day when fishing is good. Marketing of the mussels is done by women who are usually of the fishermen's families. The mussels are sold in villages within a radius of three to eight kilometres from landing centres.

World production of mussels of the genus *Mytilus* has increased from 164,000 tonnes in 1958 to 320,000 tonnes in 1969 (F. A. O, 1970 a). Holland, the largest mussel producing country harvested 105,900 tonnes in 1969, which is about 33% of the world mussel production. The other important mussel producing countries are Spain (93,700 tonnes), France (28,200 tonnes), Chile 17,500 tonnes), Denmark (16,300 tonnes), Italy (15,000 tonnes). Statistics are not available about the mussel catches in India. Jones (1950) has mentioned that thousands of maunds of the brown mussel are fished every year. At the present time the mussel beds are not as rich as in former times (Jones, 1968). The total mussel production of India may be some hundreds of tonnes per year.

Utilization Of Mussels

In India the value of mussels as nutritious food is not realized to a large extent. Mussels are usually consumed after cooking in the form of a curry. People of poorer classes boil the mussels with pieces of roots of tapioca or cassova with a little quantity of water and when they are cooked, drain and eat them. Some people eat raw mussels but this is very rare. Pearls ranging in size from a tiny pin-head to that of a pepper-corn are secreted by mussels but there is no demand for them. Empty shells of mussels are heaped and sold to lime kiln owners who manufacture lime. The shells of the brown mussel are powdered and utilized as manure in gardens and cocoanut farms.

Sea mussels are very much relished in western countries. Mussels are stated to be easily digestible and are recommended for people suffering from weak digestion (Field, 1908). Mussels are used in various ways in the West. In European countries and United States of America crushed *Mytilus edulis* is employed as bait and thrown overboard in mackerel fishing. The mud in the vicinity of mussel beds is rich in organic materials and used as manure for growing carrots and onions in Great Britain. The shells are carved and polished and ornamental articles made (White, 1937).

OYSTERS

Some of the bivalve molluscs belonging to different families are popularly known as 'hammer oysters' (Family Isognomonidae), 'pearl oysters' (Family Pteridae), edible oysters (Family Ostreidae), 'window-pane oysters, (Family Anomiidae) and ' finger oysters ' (Family Solenidae). However, whenever the name oyster is used without any prefix it means only the edible oyster. In some countries like the United States of America, Canada, United Kingdom, Japan, Korea, China (Taiwan) and Philippines large quantities of oysters are fished from natural beds and also cultured. In these countries edible oysters are considered as a delicacy. The edible oysters with which the following account deals are highly nutritious containing good quantities of glycogen, lipids, protein, Vitamins especially A, B and D and several essential minerals (Quayle 1969; Gunter and McKee, 1960). In India substantial oyster resources exist which remain unutilized but for some harvesting to meet the requirements of a small section of population for food and conversion of the oyster shells into lime. Different aspects of the biology of oysters have been studied in various parts of the world and there are thousands of scientific papers on the subject (*vide* Korringa, 1952; Yonge, 1960; Loosanoff and Davis, 1963; Galtsoff, 1964). The keen interest evinced in the study of oysters is due to their commercial importance.

As many as eleven species of oysters have been stated to occur on the Indian coasts (Awati and Rai, 1931). The occurrence of some of these species

has to be confirmed by a detailed study of material as we know little of their taxonomic characters from the known records. Four species of oysters *Crassostrea madrasensis* (Preston), *C. cucullata* (Born), *C. gryphoides* (Schlotheim) and *C. discoidea* (Gould) occur in appreciable quantities at different places on the coasts of India and are commercially important while the others are found sporadically and are of scientific interest only.

Taxonomy

Phylum Mollusca
Class Pelecypoda
Order Eulamellibranchia
Sub-Order Ostracea
Family Ostreidae
Genus *Crassostrea*

Thiele (1931) has included the family Ostreidae under the Order Anisomyria based on the nature of the adductor muscles, the anterior adductor muscle being reduced or totally suppressed in members of the Order. Pelseneer (1906) whose classification is usually followed includes the family Ostreidae in the Order Eulamellibranchia which consists of bivalves with gills composed of branchial filaments united at regular intervals by vascular junctions. Members of the sub-order Ostracea (Series according to Thiele) are monomyarian or with a very small anterior adductor muscle, the mantle is open, the foot is reduced in size, the gills are folded and the shell is inequivalve. The family Ostreidae is characterized by very much reduced foot which does not have byssus gland, the gills are fused to the mantle, and the shell is fixed to the substratum by the left valve which is larger than the right one.

Originally about a hundred species of recent oysters and 500 species of fossil oysters were described based on variations in shape, size, colour and texture of the adult shell and some of the points of difference are of little taxonomic significance (Korringa, 1952). The shape of the shell of adult oysters varies greatly under the influence of factors like nature of substratum, salinity, current velocity, exposure etc. and it has been found that it is unreasonable to erect numerous species based on these differences. Ranson (1948, 1950) distinguished oyster genera mainly on the basis of the structure of the larval shell and divided recent oysters into three genera, *Pycnodonta, Gryphaea* (synonymous with *Crassostrea*) and *Ostrea*. In *Pycnodonta* the larval shell has equal valves, there are five teeth on the provinculum and the interior ligament is present immediately following the provinculum and the adult is oviparous, the rectum traverses through the ventricle, promyal chamber is present and chalky deposits are of lamellated type. In *Ostrea* the larval shell consists of unequal valves with two teeth on each side of the provinculum, the anterior pair may be reduced, the interior ligament is placed in

the provinculum, the adult is larviparous, rectum does not pass through the ventricle, promyal chamber absent and chalky deposits of shell are lamellated.

As pointed out by Hemming the fossil species *Gryphaea arcuata* Lamarck is the type species of the genus *Gryphaea* (Korringa, 1952). Children's selection of *Gryphaea angulata* as type species of the genus *Gryphaea* is not tenable as at the time, in 1801, when the generic name *Gryphaea* was published by Lamarck, *Gryphaea angulata* was just only a name and cannot be considered as an originally included species. According to the international rules of nomenclature the generic name *Gryphaea* could be used only for fossil species and the generic name *Crassostrea* (Sacco, 1897) is the first valid name for oysters of the type *angulata, virginica, gigas, madrasensis, cucullata* etc. The distinguishing features of the genus *Crassostrea* are: the shell is very irregular in shape, attached to the substratum by the lower left valve, the hinge is toothless, with linear margin, the ligament is partly external and laminated upon a trigonal area in each valve, there is only one adductor muscle viz., the posterior adductor muscle, the adult is oviparous, rectum does not pass through ventricle, promyal chamber present and chalky deposits are lamellated.

Crassostrea madrasensis (Preston)

Synonyms

Ostrea cucullata Hornell 1910
Ostrea virginica Annandale and Kemp 1916
Ostrea virginiana Hornell 1922b
Ostrea virginiana var. *madrasensis* Moses 1928
Ostrea arakanensis Winckworth 1931
Ostrea madrasensis Preston 1916
Ostrea madrasensis Awati and Rai 1931
Ostrea madrasensis Gravely 1941
Ostrea madrasensis Paul 1942
Ostrea madrasensis Rao 1951
Ostrea (Crassostrea) madrasensis Rao 1956
Ostrea madrasensis Satyamurthi 1956
Crassostrea madrasensis Rao 1958

Common names

Tamil — *Ali, Kalungu, Patti.*
Malayalam — *Muringa, Muru.*

Description

Shell straight, shape irregular, covered by numerous foliaceous laminae, left valve deep, right one slightly concave, hinge narrow and elongated, adductor

scar sub-central, reniform and dark purple in colour, inner surface of valves white, glosssy and smooth, purplish black colouration on the inner margin of the valves (Figs. 1 C and D).

Body

A brief account of the description of the soft parts of *C. madrasensis* has been given by Moses (1928). The right and the left mantle lobes of the oyster enclose a large mantle cavity which is divisible into a lower inhalent chamber (Fig. 1 E, in. ch.) and an upper exhalent chamber (ex. ch.). In the inhalent chamber are two pairs of gills one each on the right and left sides extending forwards upto the two labial palps (l. p.) between which the mouth is present. In about the middle of the body is the adductor which runs across the two valves of the shell. It consists of a large anterior translucent portion (p. ad'.) formed of striated muscle fibres, which brings about rapid contraction that can close the shell quickly and a narrow posterior portion (p. ad'' .) composed of smooth muscle fibres, which functions as a catch muscle to fix the valves in a particular position either partially or fully open. In front of the posterior adductor is the pericardium enclosing the heart with two auricles (au.) and a ventricle (v.). The digestive system consists of a narrow oesophagus leading from the mouth, a spacious stomach (st.) closely pressed against the ramifications of the digestive gland of either side, a slightly twisted midgut with a style sac in the oral process, a long intestine (int.) partly within the oral process and partly encircling the stomach and a rectum opening into the exhalent chamber by the anus located on the dorsal side of the adductor muscle. Much branched vesicles with connective passages at the junction of the mantle with the body constitute the kidneys. The gonads of the oyster are creamy white, highly branched, tubular follicles lying below the body epithelium around the visceral organs (Rao, 1956). The follicles of the two sides almost fuse at the hinge region and are absent below the oesophagus and around the pericardium. The gonoducts of the two sides open into two separate urino-genital clefts near the adductor muscle. In fully ripe females the ramifications of the follicle tubules are clearly discernible and this is not the case in ripe males. In partly spawned oysters of both sexes the upper portion of the gonad is flabby and there is accumulation of watery fluid, while lower below there are ripe germ cells within the follicles. The amount of watery fluid in the gonads depends on the extent of spawning. Generally the fully spent female oyster presents a more flabby appearance than a fully spawned male.

Distribution in India

Sonapur, deltas of Godavari and Krishna, Gokulapalli, Pulicat, Ennur, Madras, Cuddalore, Athankarai and Kanchanagudi near Mandapam, Kerala coast and Port Blair (Andaman Islands).

Habitat

C. madrasensis is essentially a brackish water oyster. It occurs as thick beds in estuaries, backwaters, ports and harbours and only sporadically on the open coasts. The oysters are found from the intertidal zone to a depth of about 4 metres. They colonise not only rocky or concrete surfaces but also hard muddy bottom where they thrive well. The general shape of the oysters varies in relation to the substratum. Those settling on flat rocky surfaces are round, those growing on soft mud are long and narrow, and those growing on uneven surfaces have shapes which conform to that of the substratum. Oysters growing in the upper parts of estuaries possess heavier meats and more massive shells as compared to those along the coast or at the mouth of estuaries. Overcrowding results in highly irregular form (Rao and Nayar, 1956).

Maturation of gonads

The adult oysters of Madras harbour are in a partially spawned condition all round the year (Paul, 1942; Rao, 1951) under marine conditions. The oysters of Adyar backwaters exhibit seasonal changes in gonadal activity (Rao *loc. cit.*). The gonads were full or partially spent in March — April 1948, spent in May and in recovering stage in the period June — September. The gonads contained ripe gametes in September and October and were in full or partially spawned condition in the period November — January. There was recovery of the gonadal follicles in January and February but no rapid proliferation. In contrast to the ripe gonadal condition of oysters in March and April 1948 there was cytolysis and dissolution of eggs in March — April 1949 and only males were ripe. It has been suggested that the difference may be due to variations in salinity of the habitat water. The salinity of Adyar backwaters was 20 — 28‰ in March — April 1948 and much higher, 32 — 37·9‰ in March — May 1949.

In *C. madrasensis* of Ennur backwaters gametogenetic activity takes place twice in a year, once in March and again in September (Rao, 1956). Gametogenesis beginning about March is of very short duration while that beginning in September extends till December. A small or large percentage of oysters belonging to both sexes are mature throughout the year in the Ennur backwaters. In *C. madrasensis* of Athankarai estuary near Mandapam also gametogenetic activity was observed to take place twice in a year, in August–September and in March (Satyanarayana Rao – unpublished). The salinity of the estuary is very high 46·53‰ in August due to evaporation. In Athankarai estuary ripe oysters belonging to both sexes occured in most of the months in the year in high percentages (Table I). This appears to be due to the estuary remaining connected with the sea throughout the year.

In temperate waters there is a close relation between gonadal activity of oysters and water temperature (Loosanoff, 1942). Gametogenesis takes place in

spring, spawning in summer and the oysters enter resting phase in winter when the water temperature falls to extremely low levels. Loosanoff and Davis (1952) induced gametogenetic activity in hibernating *O. (C.) virginica* in winter by rearing them at higher than natural temperatures in laboratory and spawning took place at 15 C. The minimum temperature at which spawning takes place differs in the northern and southern populations of the American oyster. This is considered to be due to the populations belonging to different physiological races (Loosanoff and Davis *loc. cit.*). In Ennur backwaters water temperature has been found to vary between 25.7 C and 33 C during the year and Rao (1956) states that there has been no evidence to show that gametogenetic activity is inhibited by the lower levels of the temperature range.

TABLE 1

Percentages of ripe male and female *Crassostrea madrasensis* of Athankarai Estuary in the period August 1969–December 1970 with data on temperature and salinity of the Estuary.

Months	Ripe males expressed as percentage of total males	Ripe females expressed as percentage of total females	Water Temperature °C	Salinity ‰
August, 1969	41.6	88.8	30.5	45.8
September	17.5	50.0	30.3	51.83
October	54.5	100.0	28.3	13.13
November	0.0	94.7	28.8	30.40
December	...	...	...	...
January, 1970	100.0	100.0	28.8	7.93
February	100.0	100.0	27.8	19.79
March	69.5	80.0	27.8	25.00
April	84.2	100.0	32.2	14.37
May	71.4	100.0	28.8	31.87
June	52.6	4.5	30.5	32.97
July	50.0	0.0	27.5	42.21
August	22.2	57.1	29.0	39.19
September	76.9	83.3	30.0	38.79
October	84.2	100.0	29.6	33.67
November	72.7	91.6	26.1	17.99
December	100.0	87.5	26.8	19.06
Average	62.3	79.8	28.8	29.00

HERMAPHRODITISM

Hermaphroditism has been recorded to occur in *C. madrasensis* by Rao (1953, 1956). Hermaphrodites occurred in all the seasons. In the pre-monsoon and monsoon months oysters changing from male to female sex occur and in the post-monsoon and summer months oysters changing from female to males sex have been noted. In *C. madrasensis* of Athankarai estuary harmaphrodites showed a regular periodicity in occurrence oysters changing from male to female sex having been observed in the pre-monsoon and post-monsoon months and individuals changing from female to male sex in post-monsoon and summer months (Satyanarayana Rao - unpublished).

The type of hermaphroditism noted in the Indian species *C. madrasensis* is similar to that in the American oyster *C. virginica* and the Pacific oyster *C. gigas* and is what is termed ambisexuality or monoecism with alternative sexuality (Coe, 1943) i. e, the adults function as separate sexes in any one spawning season and sex change occurs in between two consecutive spawning seasons. On the other hand in the larviparous oysters *Ostrea edulis* (Orton 1927a, 1927b, 1933), *O. lurida* (Coe 1932a, 1934) and *O. equestris* (Gutsell, 1926) exhibit what is known as "ambisexuality or monoecism with rhythmical consecutive sexuality". In these species oysters which are males or females in the early part of the spawning season undergo sex-change in the course of the season, the ratio of the extent of the male and female germ cells differing at different periods of the breeding season. In these species, the oysters complete three sexual phases in the course of the first year and one or two phases in the succeeding years. Some males do not undergo sex change for a prolonged period. These are called "true males" (Coe, 1932b; 1934; 1943; Gutsell, 1926).

The causal factors responsible for sex change in oysters are not quite clear. The primary gonad of oysters contains undifferentiated gonia that could develop into male or female germ cells. Usually the initial sexual phase is male (termed protandry). However, in a few the first sexual phase may be female. At the conclusion of the spawning season or much before that as in larviparous oysters the reproductive follicles shrink and are in a quiscent phase. At this stage the gonads have potentiality of developing either into male or female sex. Coe (1936) observed that oyster populations living under comparatively more favourable conditions have a greater percentage of females than males. Excision of gills has been found to be accompanied by dominance of males in *C. gigas* (Amemiya, 1935). Occurrence of the commensal crab *Pinnotheres* in *C. cucullata* (Awati and Rai, 1931) and overcrowding of oysters are some of the other conditions with which dominance of males has been correlated.

Orton (1927b) suggested that carbohydrate metabolism is predominant in males while in the females it is protein metabolism which is dominant and sex

change is due to rhythmical changes in metabolism of the oysters. Biochemical studies by Egami (1951) in *C. gigas* lend support to Orton's hypothesis.

Sex ratio

In summer season when the gonads of oysters are fairly full the males are dominant (59.6%) in Ennur backwaters (Rao, 1956), females forming only 38.6%. In the pre-monsoon months the proportion of females is greater (55.7%) than that of males (41.7%). In the monsoon period in the course of which spawnlng takes place (in November and December) females continue to be the dominant sex. In the post-monsoon period as the gonadal follicles are resorbed the males preponderated over the females. Sexually indeterminate oysters occur almost throughout the year and are maximum (about 10.7%) in the pre-monsoon and post-monsoon periods at the conclusion of two periods of gonadal activity, Hermaphrodite oysters have also been recorded throughout the year in backwaters in small percentages (0.9 to 8.5%).

Spawning

Hornell (1910a) recorded peak sexual activity in *C. madrasensis* of the east coast rivers and backwaters between October–November and considered that a fall in the salinity and not arise in water temperature is the main stimulating factor. In 1922 he stated that there is a secondary peak in spawning in oysters in March–April with stray spawning in between and opined that not only a rise in temperature but also a fall in salinity induces spawning (Hornell, 1922b). Sunder Raj (1930) mentioned that a salinity range of 8.42‰–29.99‰, with a specific gravity 1.007–1.020 favours breeding and early development but this is a very wide range. Panikkar and Aiyar (1939) observed motile sperms in male oysters of Adayar river in November, 1934 and October and November, 1935. Paul (1942) recorded that the oysters of Madras harbour breed throughout the year with maximum activity between April and October.

Rao (1951) observed a main spawning period in *C. madrasensis* of Adyar backwaters between October and December and usually a second season existed in March–April. In the first spawning season the salinity of the backwaters was 22–25‰ and temperature 24–25° C. In the second season the salinity was 20–25‰ and temperature 29°–33° C. Rao (*loc. cit.*) found that oysters of Adyar backwaters exhibited natural spawning in the laboratory as well as in the field in the breeding period but failed to spawn in the field in the non-reproductive period when kept in different grades of salinity. Unlike oysters of the Adyar backwaters the oysters of the Madras harbour were in a partially spawned condition throughout the year as noted by Paul (1942). Maturation of gonads and production of ripe gametes in April 1953 and 1954 in oysters of Ennur backwaters was not followed by spawning while maturation in October in these two years was followed by successful spawning.

Early Development

The early development of the oyster has been partially studied by Moses (1928) and Devanesan and Chacko (1955). The fully ripe egg is spherical and ranges between 0·051 mm and 0·085 mm in diameter. One polar body extruded within twenty minutes after fertilization and two indentations and later a third indentation appeared and the egg became divided into a three-celled structure. One of the three cells divided several times rapidly and the resulting cells which were small were situated on the undivided two cells. About an hour after the first segmentation the two cells underwent division and by this time the cap of cells at the top descended and enclosed them resulting in the formation of blastula. The blastula is spherical at first and later becomes elongated and flattened at the top and bottom and develops a depression at the bottom. The two ends of the elongated and flattened blastula are brought nearer as to enclose a hollow depression and the gastrula is formed which develops shell gland, a prototroch and a circlet of cilia anteriorly and becomes the veliger. The shell gland invagination becomes everted and the walls of the invagination spread laterally over the body of the larva and the middle portion of the body becomes flattened.

Occurrence of larvae in plankton

Oyster larvae have been observed in the Adyar backwaters between the middle of March and the first week of May (Rao, 1951). There was a progressive decrease in the abundance of larvae during the period. The salinity varied between 20·32‰ and 28·59‰, and the average temperature was 32·8° C. As the average water temperature reached 33·2° C in April heavy mortality was observed. Larvae again appeared in the backwaters from 26th November to third week of January with peak numbers in the end of this period. The average salinity was 29·01‰ and temperature 24·2 — 25·2° C in this period. The larvae appear to require slightly higher salinities for setting than those (22 — 26‰) at which spawning takes place.

Under marine conditions of the Madras harbour larvae of *C. madrasensis* occur in plankton in all the months with maxima in the periods May — July and November — January corresponding to times of high temperature and low salinity respectively (Rao *loc. cit.*).

Spatfall

From field observations and experiments conducted in the laboratory to find out the effect of different grades of salinity prepared with sea water and estuarine water on the spatfall Rao (*loc. cit.*) found that in the Adyar backwaters conditions were favourable for spatfall only when the backwaters were in communication with the sea and the salinity increased to 28—30‰. Chidambaram

and Dinamani as cited by Devanesan and Chacko (1955) also have recorded that there was no spatfall in Ennur backwaters between 26th January 1948 and 17th November 1949 during which period the sand bar at the mouth of the backwaters remained closed and there has been spatfall between 18th November 1949 and 18th June 1950 when the backwaters were connected with the sea. The information collected clearly shows that some factor present in sea water as yet unascertained facilitates spawning and spatfall in *Crassostrea madrasensis*. Rao (*loc. cit.*) states that the periodical inflow and outflow of tidal and flood water with the tidal amplitude and the circulation of water that is maintained constantly when the backwaters and estuary are in communication with the sea may influence spawning and spat setting. The pH of the backwaters as well as coastal waters of Madras fluctuates over a very small range of 8·3 — 8·6 (Rao *loc. cit.*) and this could be considered to play no role in the success or failure of spatfall.

Growth

Hornell's data (1910a) on spat of oysters of Ennur shows that the spat grow to a size of 27 mm in $1\frac{3}{4}$ months. Paul (1942) has recorded that oyster spat grow to 0·8 mm, 4·4 mm, 6·3 mm, 6·5 mm, and 12 mm in length (height) in 3, 10, 13, 16 and 19 days respectively in Madras harbour. Rao and Nayar (1956) observed that in the first week oyster spat showed, when reared in laboratory growth rate similar to that observed by Paul (*loc. cit.*) but later it was poor and spat attained a height of 10·3 mm in 61 days. Rao and Nayar recorded that in the third week of November spat ranged between 2 mm and 7·5 mm in height with an average value of 4·5 mm in the Adyar estuary (Table II). In December when the spat was one month and three weeks old a maximum size of 35 mm and an average size of 18 mm were recorded. In January $2\frac{1}{4}$ month old spat had a maximum height of 45 mm and an average height of 26 mm. February samples were almost similar to those in January. In March the five month old oysters reached a maximum size of 54 mm and an average size of 30·4 mm and six month old oysters a maximum size of 61 mm and an average size of 36·8 mm. There was very little increase in the maximum height of the spat between May and September but the average height showed an increase during this period. In October when the sand bar at the mouth of estuary opened the oysters put forth fresh shoots and by the end of the month a maximum height of 84 mm and an average height of 50·6 mm were recorded. One year and 4 months old oysters showed a maximum height of 109 mm and an average height of 63·7 mm. The growth rate of the tropical oyster *C. madrasensis* is much faster than that in *Ostrea edulis* of Thames Estuary, which ranges between 5 and 35 mm with an average of 19·6 mm at the end of one year (Orton 1926, 1937). The rate of growth of *C. madrasensis* is about the same as that in *C. virginica* determined by Ingle (1950) and Menzel (1951). *C. virginica* grows to a height of 50 mm in 2 months, 75 mm in 4 or 5 months and 100 mm in 9 months after setting.

TABLE II

The maximum, minimum and mean height and modal values of the populations of oyster spat in samples from the Adyar Estuary during 1953-1955 (after Rao and Nayar, 1956)

Date	Min. Height (mm)	Max. Height (mm)	Mean Height (mm)	Modal Height (mm)
November 1953				
23rd	2·0	7·5	4·5	4·5
30th	1·5	8·5	4·1	4·5
December 1953				
7th	3·1	12·5	7·8	7·5
14th	2·0	25·0	9·3	7·5
21st	6·0	24·2	13·9	10·5
28th	10·0	35·0	18·0	13·5
January 1954				
6th	10·0	32·0	19·6	
27th	8·0	37·0	20·9	22·5
29th	15·0	45·0	26·6	
February 1954				
1st	13·0	28·0	21·8	
15th	17·0	38·0	25·7	22·5
26th	15·0	40·0	26·3	
March 1954				
1st	17·0	50·0	28·8	
8th	20·0	36·0	27·1	28·5
22nd	21·0	48·0	33·4	
29th	27·0	54·0	34·2	
April 1954				
5th	17·0	42·0	29·4	
12th	23·0	57 0	39·2	40·5
19th	18·0	55·0	40·4	
26th	28·0	61·0	39·2	
May 1954				
3rd	22·0	52·0	30·5	
10th	27·0	50·0	38·4	43·5
17th	22·0	56·0	42·7	
25th	30·0	53·0	37·4	
June 1954	24	57·0	36·2	40·5
July 1954	26	61·0	45·4	40·5
August 1954	26	65·0	48·4	49·5
September 1954	27	65·0	46·4	52·5
October 1954	27	84·0	50·6	55·5
November 1954				
1953 Yr. Cl. 15th	25	96·0	55·5	52·5
1954 Yr. Cl. 15th	1·5	6·0	4·2	4·5
1954 Yr. Cl. 22nd	1·5	10·0	5·2	4·5
1954 Yr. Cl. 29th	1·5	22·5	7·6	7·5
December 1954				
1953 Yr. Cl.	31·5	102·0	57·9	52·5
1954 Yr. Cl. 7th	2·5	25·2	12·1	13·5
1954 Yr. Cl. 13th	1·5	33·0	9·6	10·5
1954 Yr. Cl. 20th	4·0	32·0	13·2	10·5
1954 Yr. Cl. 27th	2·5	30·0	14·6	19·5
January 1955				
1953 Yr. Cl.	23·0	107·0	60·5	61·5
1954 Yr. Cl. 3rd	7 0	32·0	15·2	
1954 Yr. Cl. 10th	4·0	31 0	15·1	
1954 Yr. Cl. 17th	8·0	30·0	16·1	13·5
1954 Yr. Cl. 24th	6·0	32·0	16·4	
1954 Yr. Cl. 31st	2·0	33·0	13·8	
February 1955				
1953 Yr. Cl.	32·0	109·0	63·7	No def. Mode
1954 Yr. Cl. 7th	0·5	29·0	12·4	
1954 Yr. Cl. 14th	3·5	41·0	23·1	
1954 Yr. Cl. 21st	8·0	31·0	21·3	22·5
1954 Yr. Cl. 28th	10·0	49·0	24·4	

Distinct zonation has been seen on the shells of oysters collected during or after the opening of the bar in Adyar estuary (Rao and Nayar *loc. cit.*); there is a whitish zone of earlier formation followed by recently formed darkish one. The two zones are separated by an interruption line or ring. The interruption lines are annual and are formed during the period of unfavourable growth when the bar is closed every year.

The growth rate of the oysters is rapid between October and March, moderate during the period April and June and very poor between July and September. Growth is favoured when the estuary is in communication with the sea and it is markedly slackened when the bar is closed. An abundant supply of food organisms is believed to be responsible for the fast growth of the oyster when the bar is open. Fluctuations in pH are not marked in the Adyar estuary and there is no relationship between them and growth of the oyster.

About 23% of the oysters of Adyar estuary reach marketable size, 70 mm and above when 16 months old. A majority of the oysters attain marketable size only in the third year of their life.

Food

Moses (1928) has stated that diatoms are the main food of the oysters. He has mentioned that half the amount of the contents in stomachs of the oysters consists of unrecognizable plant detritus and the diatoms *Biddulphia, Rhizosolenia, Chaetoceros, Coscinodiscus, Pleurosigma* and *Navicula-Ceratium*, Foraminifers, Peridinians, *Dinophysis*, sponge spicules, setae of polychaete larvae and Daphnids have been observed in the stomachs of oysters.

The diatoms *Coscinodiscus excentricus, Rhizosolenia cylindrus, Chaetoceros indicus, Bacillaria paradoxa, Biddulphia sinensis, Nitzschia seriata, Pleurosigma angulatum* and *Guinardia flaccida* were recorded in the stomachs of oysters of Ennur by Jacob and Nelliyander as reported by Devanesan and Chacko (1955) and it was assumed that the oysters feed on the diatoms. *Nitzschia, Pleurosigma* and *Navicula* were noticed in large numbers in the months of December, January and February. Our present knowledge about the diet of oysters is imperfect and the subject requires intensive study.

Parasites, Pests and Predators

The Polychaete *Polydora ciliata* and *Polydora armata* (identified by G. P. K. Achari) have been recorded on the oysters of Athankarai estuary. *P. ciliata* which is more common causes severe damage to the shells by making extensive tubular burrows. The oysters attacked by the worms are weak and the meats of the oysters are very poor in quality and watery which could be attributed to the

oysters utilizing more than usual energy for secretion of shell. Korringa (1952) states that by bathing oysters parasitized by *Polydora* for 16 hours in fresh water or for 3 hours in $\frac{1}{2}$% solution in sea water of the ammonium salt of dinitro-ortho-cresol the worms could be killed and the oysters soon exhibit better growth.

Deposition of silt and mud causes mortality of oysters. The algae *Polysiphonia* sp., *Enteromorpha* sp. and Myxophyceae occur as epi-flora of oysters. *Polysiphonia* forms a thick layer on the oysters in the upper portion of Athankarai estuary. Mussels of the genus *Modiolus* are found in large numbers on oysters at Pulicat, Ennur and Athankarai. The barnacle *Balanus amphitrite* is moderately common on oysters at Athankarai. The drill *Thais rudolphi* has been seen boring into young oysters near the mouth of the Athankarai estuary on a few occasions.

The crabs *Scylla serrata* and *Thalamita crenata* feed on the oysters and are predators. Fortunately the well-known enemies of oysters such as starfishes and limpets are rare on oyster beds of Indian coasts.

Quality of meat and percentage edibility

The percentage edibility (weight of meat of oyster expressed as a percentage of total weight of the oyster) has been reported by Venkataraman and Chari (1951) to be low in July and fairly high in October with corresponding variations in fat content. The low levels in July have been attributed to growth of the oysters and maturation of gonads and increase in October to intensive feeding prior to spawning. Rao (1956) found two periods in the year when the meat weights and percentage edibility were high, May – June and September–October and a fall was noticed in the values in periods succeeding them following spawning. The average percentage edibility of oysters of Athankarai estuary was observed to be high in the months January-February, April and November-December (Table III).

Chemical composition

Venkataraman and Chari (*loc. cit.*) have studied the seasonal quantitative changes in water, fat, protein, glycogen, ash, phosphorus, calcium, iron, and copper contents of oysters of Ennur (Table IV). The oysters were found to accumulate fat during the period August-November and a maximum of 2.71% wet wt. was recorded in November. The fat content decreased to 1.5% in January after spawning. The protein content varied between 5.72% and 13.31% and glycogen between 0.44% and 5.85%. The data did not reveal well defined changes in glycogen content in relation to gonadal condition in contrast to the findings of Okazaki and Kobayashi (1928) and Masumoto *et al.* (1934) in Japanese oysters. The water content of oysters ranged between 76.67% and 85.04% and showed an inverse relation to fat content. Kasinathan (1964) observed that the saponification value of male oysters is higher thau that of

females and the iodine number of fat of the females is higher than that of males.

TABLE III

Average meat weight and percentage edibility of *Crassostrea madrasensis* of Athankarai Estuary in successive months in the period August, 1969-December, 1970.

Months	Average meat weight of oysters (gm)	Average percentage edibility of oysters
August, 1969	6·12	4·60
September	5·67	4·95
October	7·10	5·31
November	7·74	5·49
December	...	...
January, 1970	10·82	7·13
February	8·33	6·55
March	7·33	4·92
April	8·86	6·86
May	8·10	5·31
June	8·73	4·97
July	6·46	3·10
August	8·57	4·40
September	9·03	4·30
October	8·01	4·42
November	10·27	5·95
December	8·93	5·01

FISHERY

The oysters are fished at Pulicat, Ennur, Madras, Kanchanagudi (near Mandapam) and on Kerala coast. The oysters are gathered by separating them from the rocky substratum or dead oysters to which they adhere, using stones in the vicinity or a hammer. The oysters are fished by men and women of fishermen community. The oysters from Pulicat, Ennur and Cochin are supplied mostly to a few modern hotels in Madras and Cochin. The general public do not know of the nutritious nature of oysters and only some persons who frequent western style hotels and very poor people usually fisherfolk eat oysters. On the south-west coast oysters are fished usually for the massive shells which are

TABLE IV

Seasonal changes in chemical composition of *Crassostrea madrasensis* of Ennur backwaters (after Venkataraman and Chari, 1951)

Months	Edibility %	Water %	Protein %	Fat %	Ash %	Glycogen %	P_2O_5 %	C_aO %	Iron mg %	Copper mg %
October, 1949	...	85·04	6·93	2·22	1·29	...	0·307	0·315	5·32	...
November	10·67	77·49	8·07	2·71	2·02	...	0·364	0·555	...	2·14
December	8·22	81·19	13·31	1·79	2·00	1·12	0·388	0·170	11·70	2·56
January, 1950	8·36	82·71	10·13	1.54	1·80	0·46	0·389	0·261	13.00	3·27
February	9·23	82·87	11·07	1·95	1·01	0·44	0·419	0·121	12·92	3·12
March	9·22	80·11	10·81	1·74	1·50	1·62	0·385	0·377	10·21	2·79
April	5·93	79·23	10·80	1·90	2·06	1·52	0·440	...	2·53	7·69
May	8·92	79·54	8·18	1·69	1·48	...	0·305	0·076	8·72	3·17
June	5·48	79·77	10·62	1·69	1·61	2·77	0·331	0·154	11·63	3·95
July	6·99	76·67	9·88	1·49	1·75	5·63	0·328	0·060	12.21	2·96
August	10·92	78·57	10·30	2·40	1·51	3·02	0·472	0·088	6·83	2·78
September	10·37	78·63	9·65	2·23	1·11	3·12	0·229	0·072	10·85	1·45

used to strengthen banks of backwaters. Oysters have been removed indiscriminately from natural beds at Pulicat, Ennur, Tellicherry, Beypore and Vembanad in the past but still there are large beds which should be protected by the government by prohibiting capture of young oysters, fixing a closed season and regulating the extent of fishing.

Oyster Culture

It is necessary to practise oyster culture as continuous fishing of oysters from natural beds will lead to destruction of stocks. As pointed out by Hornell (1910b) after visiting the famous Arcachon oyster farm near Bordeaux in southern France, oyster culture could be done on the east coast adopting the methods employed in Arcachon with such modifications as local conditions and economy make necessary. To mention briefly, in Arcachon the oyster spat are collected on tiles lined by a mixture of lime and sand in the season when spatfall takes place, the spat are removed from the tiles after a period of growth in January and then reared in cases kept in protected backwaters known as "oyster parks." Great care is taken of the growing oysters with periodical cleaning and removal of epiflora, epifauna, slime and mud that are injurious to the well-being and healthy growth of the oysters; predators like crabs and fishes are prevented from entering the parks by construction of a palisade of poles around the parks. Predators which may enter through crevices in between poles of the palisade are caught. In Japan the oysters *Crassostrea gigas* and *C. rivularis* are cultured on a large scale. Spat are collected on bamboo poles, tree branches, tiles, shells or stones, the young oysters are removed after some months and grown in bunches attached to wire or ropes hanging from a large number of racks, rafts or long lines the latter two being held in position using floats and anchors. There is also an important industry of seed oyster production in Japan. For producing seed oysters the spat are collected as in the case of culture of adult oysters, allowed to grow till some time when ropes holding clusters of young oysters are placed on high grids where they are exposed for several hours daily at ebb tides. The strongest oysters only survive this treatment which lasts till several months. Those that survive develop a gasket like seal which enables them to retain some sea water during periods of exposure and these seed oysters are shipped to other places in Japan for culture. The seed oysters are largely exported across the Pacific to America (Cahn, 1950).

Crassostrea gryphoides (Schlotheim)

Synonyms

Ostrea gryphoides Newton and Smith 1912
Ostrea gryphoides Awati and Rai 1931
Crassostrea gryphoides Durve and Bal 1961

This species shows resemblance to *C. madrasensis* and is distinguished from the latter in the shell being broad, roundish and more bulky; there is a prominent central groove with elevations in the sides on the hinge of the left valve, the adductor muscle scar is oblong and pearly white and the entire inner surface of valves is white and glossy.

Description

Shell oblong, narrow in the anterior margin and broader in the posterior margin, laminated, lower valve very thick, especially in the anterior region below the ligamental area, ligamental area drawn out to a considerable distance, broad and has a deep groove in the middle; it generally curves to the left and in some to the right, transverse and longitudinal striations in groove area; upper valve thin, flat and opercular; no denticles on the margin; interior of valves white and glossy; muscle scar more or less heart-shaped and pearly white (Fig. 2 A).

Distribution in India and Pakistan

From Cutch to Karwar coast and on Cuttack coast. The species is represented also in Karachi harbour and Sind coast (Pakistan).

Habitat

This species occurs in estuaries and backwaters. It is found in the low tide zone. Sometimes it occurs at depths of 5 to 7 metres. The species is represented in almost every estuary and backwater of the Maharashtra coast.

Maturation of gonads

In *C. gryphoides* of Kelwa near Bombay gametogenetic activity commences in late April or May (Durve, 1965). In the beginning of June the oysters show active gametogenesis and rapid growth of follicles. Spermatids and spermatozoa are found in large numbers in males and mature ova in females. Towards the end of June almost all oysters are mature but stray numbers of oysters in resting phases are also present. Spawning takes place in the monsoon period between July and September. In the post-monsoon period October to mid-November the gonads are in indeterminate phase with the follicles shrunken and containing phagocytic cells. In the winter (November to February) the gonadal follicles

Fig. 2. A. *Crassostrea gryphoides* (Schotheim). B. *Crassostrea cucullata* (Born). C and D Internal view of right and left valves of *C. cucullata*. E. Anatomy of *C. cucullata* (after Awati and Bal, 1931). ad., adductor muscle; an., anus; c. aff. v., common afferent vessel; ex. ch., exhalent chamber; g., gonad; g. d., gonidial ductules; gl., gills; go. d., gonidial duct; labial palps; mt., mantle; r. d., renal duct; u. g. g., urinogenital groove; v.m., visceral mass. F. *Crassostrea discoidea* (Gould).

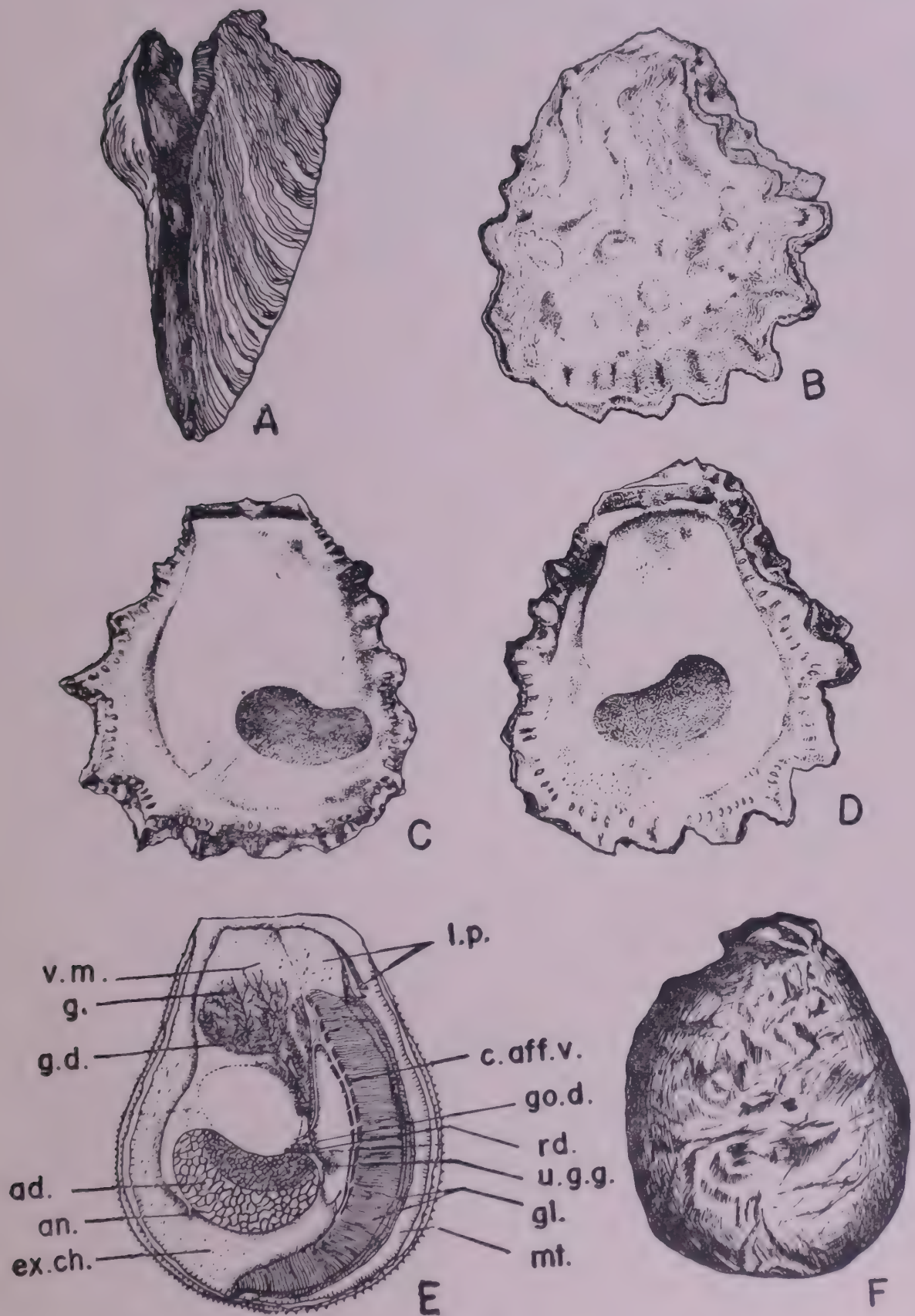

Fig. 2

are in the resting phase and sexes cannot be distinguished. The gonads are in this condition till April.

Sex Ratio

Alternate predominance of males and females has been recorded between April and June in Kelwa waters (Durve, *loc. cit.*). Females form the dominant sex till August when there is a marked fall in salinity and temperature. Males are dominant in September and October when there is a rise in the salinity. The variations in the sex ratio do not show any correlation with salinity and temperature.

Spawning

Spawning takes place in Kelwa waters between July and September (Durve, *loc. cit.*). As observed in *C. madrasensis* of the east coast by Hornell (1910a) and Rao (1956) it is stated that a fall in salinity following monsoon rains is the main stimulant to spawning in *C. gryphoides* also. An optimum range of salinity 13·15 -- 28‰ favours spawning. Spawning continues till the end of July and early August when very low salinities (3·42 – 6·98‰) prevail. Males exhibit closer correlation with lower salinity than females in regard to spawning activity. Spawning was over in females earlier than males which continued to spawn in October and early part of November when there was a well-defined rise in salinity.

Water temperature varied between 19·4° C in February and 33·4° C in May, 31° C in July and 27·4° C in September and was 31·8° C in October. Durve (*loc. cit.*) considers that the above changes in water temperature do not have any role in spawning activity.

Growth

Spatfall begins in Kelwa backwaters in July and extends till September (Durve and Bal, 1962). The average height of spat at the end of July, August and Septemper, 1957 were 2·5 mm, 4·2 mm and 7·8 mm with a monthly increase of 2·5, 1·7 and 3·6 mm respectively. The rate of growth during the above three months is slow compared to that in the succeeding period October-February, 1958. In the months March, April and May growth rate was retarded being 1·0, 1·0 and 1·5 mm respectively. Between June and August there is no increase either in the modal or mean values of the height of spat.

The rate of growth of spat of *C. gryphoides* is slower as compared to that in *C. madrasensis*. The spat of the former species exhibit a maximum growth of 37·2 mm and an average growth of 21·3 mm in height in six months. The corresponding figures for *C. madrasensis* are 60 mm and 40 mm respectively. At the end of one year *C. gryphoides* attains a maximum size of 47·9 mm and an average size

of 33·8 mm compared to sizes of 84 mm and 51 mm recorded by Rao and Nayar (1956) in *C. madrasensis*. Durve (1962) states that a large percentage of adult *C. gryphoides* put on fresh marginal shoots during the period September to March and considers that during this period growth is vigorous. After March the shell shoots begin to become dark and opaque. *C. gryphoides* grows to a height of 15 to 17 cm. On the Sind coast the species attains a large size of 30 to 38 cm.

Durve (*loc. cit.*) opines that water temperature in Kelwa which varies between 25·7 and 33·4° C (Durve and Bal, 1960) may not influence growth in *C. gryphoides*. He finds correlation between salinity values and intensity of growth. Rate of growth is rapid in the post-monsoon period and winter, October to February when the salinity is moderate, it is retarded in the period of constant high salinity (March – May) and there is almost no growth in the period July – August. Durve's observations are similar to those of Rao and Nayar (1956) stating that very high salinity conditions bring about a retardation in growth rate of *C. madrasensis* and also constantly low salinities bring about a marked decline in growth under tropical conditions.

Food

Diatoms belonging to as many as twenty genera and detritus have been recorded in the stomachs of oysters of Bombay coast (Durve, 1964b) and have been considered to be food of the oysters. *Coscinodiscus, Thalassiosira, Biddulphia, Cocconeis, Achnanthes, Diploneis* and *Synedra* were the dominant diatoms found in the stomachs. Detritus was present in the stomachs throughout the year. Diatoms were absent in stomachs between June and August when detritus also was low. Feeding activity as determined by stomach contents increased from October immediately after spawning and was as its peak from December to February. Protozoa and metazoa were not recorded except for a nauplius and some pieces of bodies of crustaceans.

Quality of meat and percentage edibility

C. gryphoides of Kelwa are fatty and cream-coloured from late October or November to June and the quality is low in the spawning period, July to September due to discharge of reproductive products (Durve, 1964a). The percentage edibility and condition index of *C. gryphoides* showed similar pattern of seasonal changes corresponding to gonadal condition of oysters. The values for the two measures are high in the period January to June and show a steep fall in July – September during the spawning period. From October as the oysters begin to recover after breeding season both the percentage edibility and index of condition rise and are high from December till July. Durve states that the fall in percentage edibility of females in the spawning season is much more rapid than in males.

Durve (*loc. cit.*) calculated the coefficient of correlation between depth of oyster and index of condition and observed that differences in depth did not affect the index of condition but the latter was found to vary with the height of the oyster. The meat volume bears a relationship to cavity volume but this is said to vary in different months.

Chemical composition

The seasonal changes in the content of water, fat, protein, glycogen, calcium and phosphorus and calorific values of the oysters have been studied by Durve and Bal (1961). The water content was found to increase during the spawning season and it has been attributed to change in the physiological state, the nutritional conditions and salinity. Water content of the oysters shows a reciprocal relationship to the content of fat, glycogen and protein. The maturing and mature oysters accumulate fat, glycogen and protein and the percentages fall in the spawning season in July – September. There is re-accumulation of the organic constitutuents from October. The fat content of the oysters varied between 0·48 and 3·20% wet wt., glycogen content between 0·69 and 7·01% and protein content between 2·79% and 9·89%. The calcium and phosphorus values are higher in the spawning period when there is a fall in the weight of the meat and organic constituents. The calorific value of the oysters is high throughout the year with the exception of the period July – October when there is a fall due to loss of fat, glycogen and protein.

Parasites

Pinnotheres sp. has been observed to infest *C. gryphoides* (Durve, 1965) but the incidence of the parasitic crab is very low. Only five out of several hundreds of oysters examined were parasitized by the crab. The oysters infested were male, female or sexually indeterminate and none of them were hermaphrodite. So it has not been possible to find out if the presence of the crab causes sex change as suggested in *C. cucullata* by Awati and Rai (1931). The parasitized oysters are of poor quality and this is attributed to interference with the normal food supply of the oysters.

Fishery

This species is fished from large natural beds that exist in backwaters, creeks and similar habitats from north Kanara to Kutch. An axe like instrument called 'koodal' is used to remove the oysters (Rai, 1932). The important fishing centres for this species are Malad, Boisar, Satpati creeks, Palghar, Sanjam Kalve, Dahisar and Navapur on Bombay coast and Alibag, Ratnagiri, Jaytapur, Malwan, Vengurla, Goa, Karwar, Gangawali Tadri and Honavar south of Bombay. Thousands of oysters of this species and *C. cucullata* are collected and sold to hotels, clubs and private individuals in Bombay and other places.

Young oysters are dislodged from natural beds near Bombay and planted on hard ground by a few fishermen. The oysters are allowed to grow upto marketable size and then sold. The species is suitable for culturing.

Crassostrea cucullata (Born)

Synonyms

Ostrea forskalii Chemnitz 1785
Ostrea cucullata Born 1890
Ostrea cucullata Hornell 1922 b
Ostrea cucullata Awati and Rai 1931
Ostrea forskalii Gravely 1941
Ostrea forskalii Satyamurthi 1956
Crassostrea cucullata Rao 1958

The Australian oyster *Ostrea (Crassostrea) commercialis* is considered as a synonym of *O. (C.) cucullata* but Iredale and Roughley (1933) hold the view that it is a distinct species. The salient characteristics of the Australian oyster are the left valve is rather deep, the right valve is nearly flat, both valves radially crumpled (plaited), colouration is bluish externally, whitish internally, hinge is of moderate size and hinge line short.

Description

Shell more or less trigonal, sometimes oblong, extremely hard and plaited, plaits more or less angular, generally small, lower valve thick, overlapping at margin, hooded under the margin, hinge elongated frequently produced at the apex; upper valve flat or slightly convex in the middle, plaited towards the margin, greater portion of the margins of both upper and lower valves denticulated; muscle scar oblong and striated (Figs. 2 B, C and D).

The morphology of this species has been studied by Awati and Rai (1931). The general structure of the body (Fig. 2 E) is similar to that of *C. madrasensis*.

Distribution in India

All along the east and west coasts of India.

Habitat

The oysters occur firmly attached to sandstone, granite boulders or coralstones in the intertidal region in brackish waters and mouths of estuaries. They are also found on the rocks of open coasts. This species is primarily an inhabitant of the midlittoral zone where it occurs in large numbers but the oysters are found in the supralittoral fringe also due to the availability of suitable substratum. They are

very hardy animals since they survive in spite of the very high temperatures to which they are subjected to in the day-time on the rocks on which they live.

Reproduction

We do not have precise information about the period at which gametogenesis takes place in this species during the course of the year. From the settlement of spat on cultch kept on Bombay coast Awati and Rai (1931) concluded that the species spawns almost throughout the year with the exception of the monsoon period, middle of June to the end of September. Spawning commences in October when the density of seawater is 1·021. Spawning activity is not intensive in the winter due to low salinity of the sea water. The main spawning season is from March to June and there is a slack spawning season from October to February when spatfall is restricted and irregular. A striking feature about reproduction in this species is that it does not breed during the monsoon period when the other species *C. gryphoides* and *C. madrasensis* spawn. Awati and Rai *(loc. cit.)* have suggested that salinity and temperature may be influenceing spawning in this species. The higher levels of salinity and temperature appear to favour spawning and spatfall in this oyster.

In the Australian oyster *O. (C.) commercialis* also spawning occurs in several months of the year (Roughley, 1933). The oysters rapidly mature during the spring season and there is spawning in December and January. Spawning has also been observed again in summer months. In addition spatfall was recorded in November also.

Sex change

Awati and Rai (1931) have recorded that a great majority of the oysters parasitized by the crab *Pinnotheres* sp. are either males or hermaphrodites and the numbers of females is very small. From this the authors have inferred that the crab usually of female sex which lies attached to the gills in the inhalent chamber may be responsible for sex change in the oyster by reducing the food supply of the oyster or by inducing a change in the metabolism.

Hermaphroditism

Hermaphrodites have been stated (Awati and Rai *loc. cit.*) to occur chiefly in the monsoon season and at other times hermaphrodites have been rare. Hermaphroditism has been attributed to deficient food supply and unhealthy condition in the monsoon period

Sex ratio

Out of 794 oysters examined by Awati and Rai *(loc. cit.)*, 41·7% were found to be males, 56·4% females and 2·9% hermaphrodites. Information is not available about the proportion of the sexes in different months of the year.

As already mentioned the crab *Pinnotheres* has been found to infest the rock oyster. The majority of the oysters which are infested are males (82%) and the incidence of the crab is very low in the case of female and hermaphrodite oysters (10% and 6% respectively). *Pinnotheres* infesting the oysters have been found to belong to female sex. Sea-weeds, hydroids, barnacles and other sessile forms grow on the shells and either make shell weak or clog the paths of water currents.

Fertilization

Artificial fertilization has been successfully accomplished in the rock oyster by Awati and Rai (1931) who have also studied early development. Fertilization was effected in a mixture of 3 parts of sea water and one part fresh water. When spermatozoa and ripe eggs are put in the water spermatozoa cluster around eggs and finally one spermatozoan fertilizes the egg.

Development

The first polar body is budded off 35–40 minutes after mixing sperms and eggs and the second polar body after another five minutes. First segmentation division takes place after another five or ten minutes resulting in a micromere and a bigger macromere. The micromere divides repeatedly and forms an outer layer enclosing a macromere. After sometime the macromere also divides and the resulting cells constitute the lining of the embryonic gut. The micromeres become ciliated and surround the macromeres except at the point where the blastopore is situated. Gastrulation takes place through epiboly as well as invagination. The larva assumes a disc-like flattened form. Then a depression appears on the surface, which grows deeper progressively and this becomes the digestive cavity. The larva becomes almost spherical and swims rapidly by means of cilia. Later, the larva develops a pre-oral circlet of long cilia at the pre-stomial region. The larva is trochophore larva. The mouth of the larva lying below the pre-oral circlet of cilia leads into the oesophagus which is followed by the stomach, a short gut and rectum which opens through the anus. The larva swims very swiftly near the surface of water.

Quality of oyster meat

The meat of *C. cucullata* of Bombay coast is in the best condition between April and June (Awati and Rai, 1931).

Fishery

The fishermen collect the oysters using a hand-dredge consisting of a net attached to a triangular frame made of bamboo with a handle, a spade, a pick-axe and a knife with large blades. The oysters are sold either as they are or after

shucking. The shucked meats are put in sea water until they are sold in the markets. This species has a delicate flavour and is esteemed (Rai, 1932). Thousands of oysters are fished and supplied to hotels and clubs in Bombay and mofussil towns.

This species also is not cultured in India but for collection of young oysters by some fishermen of Bombay coast who grow them on hard ground in the lower part of the intertical zone and sell them when they attain a size of about 85 mm in height.

Crassostrea discoidea (Gould)

Synonyms

Ostrea discoidea Awati and Rai 1931
Crassostrea discoidea Rao 1958

Description

Shell large, flat, rounded, foliaceous with conspicuous lines of growth, lower valve sligtly concave, ligamental area small, upper valve of the same size and shape as the lower and slightly convex, inner surface of valves clear and nacreous, no denticulations present, muscle scar oblong and cloudy white or smoky white in colour (Fig. 2 F).

Distribution in indian region

North Kanara to Kutch. The species is represented at Dwarka, Bombay (Mahim), Ratnagiri and Jaytapur. It is also found in Karachi and Sind creeks (Rai, 1932)

This species occurs attached to rocks in deep waters of the littoral zone. The oysters grow to a size of about 15 cm in height and are fairly abundant at Dwarka, Bombay and Jaytapore. We do not have information on the biology of this species.

Crassostrea crista-galli (Linnaeus)

Synonyms

Mytilus crista-galli Linnaeus 1758
Ostrea cristagalli Lamarck 1819
Ostrea (Lopha) cristagalli Standen and Leicester 1906
Ostrea cristagalli Hornell 1922b
Ostrea crista-galli Prashad 1932
Ostrea cristagalli Satyamurthi 1956

DESCRIPTION

Shell broadly rounded or subquadrate in shape, margins of valves thrown into very deep, sharp angular plaits, the teeth-like processes of the two valves interlocking with each other. Outer surface of folds have diverging close set granulated striae. Colour of shell varies from brownish to violet. Internal surface of valves greyish white.

DISTRIBUTION IN INDIA

Tanjore coast, Palk Bay, Gulf of Mannar, Okha.

This species is known as cock's comb oyster due to its shape that resembles cock's comb. Generally solitary specimens are found cemented to stones or coral stones in small numbers. In Pishotra in Okha district oyster beds of this species exist but they are not commercially important as the oysters are of small size and have irregular growth.

CRASSOSTREA(?) FOLIUM (Gemlin)

SYNONYMS

Ostrea folium Chemnitz 1781
Ostrea folium Gmelin 1791
Ostrea folium Reeve 1873
Ostrea folium Satyamurthi 1956
Ostrea folium Kundu 1965

DESCRIPTION

Shell broadly ovate in outline, left valve deeply concavely excavated along the middle to fit surface of attachment. The right valve is raised into a characteristic broadly rounded tube-like, longitudinal rib along the middle corresponding to the excavation of the left valve. On either side of this medial, rib-like elevation the shell is thrown into numerous rounded folds which diverge away from the middle line. The surface is more or less smooth except for a few thin, overlapping laminae towards the margin. The shell is of a pale brownish purple colour.

DISTRIBUTION IN INDIAN REGION

This species is a rare one found in stray numbers in Pamban and Gulf of Kutch. Sometimes it occurs attached to twigs on the coast.

From the collections made in the Indian region Awati and Rai (1931) have described four more species of oysters viz., *Ostrea cornucopia* Chemnitz, *Ostrea glomerata* Gould, *Ostrea belcheri* Sowerby and *Ostrea quercina* Sowerby. They

mention that yet another three species *O. crenulifera* Sowerby (synonymous with *O. plicata* Chemnitz), *O. bicolor* Hanley and *O. lacerata* Hanley have been reported in Memoirs and Proceedings of Manchester Literary and Philosophical Society, Vol. 7, 4th Series. The descriptions of the four species of oysters given by Awati and Rai (*loc. cit.*) are given below. It is doubtful whether they are referable to the genus *Crassostrea*.

Crassostrea(?) cornucopia (Chemnitz)

Shell more or less oblong, solid, with lines of growth, transverse striations well-marked, longitudinal fine striations present, plaited, plaits deep and rounded; lower valve larger than the upper with a tendency to grow upwards, with a deep cavity, the latter extending under the hinge margin; ligamental area highly developed, drawn out to a very considerable distance, tapering, with a distinct groove; upper valve flat, opercular in form; no denticulations present; muscle scar more or less oblong.

This species is said to have a superficial resemblance to *O. (C.) cucullata*.

Distribution in India

It is generally found among clusters of *C. cucullata*. The species has been recorded from rocks around Marmagoa.

Crassostrea(?) glomerata (Gould)

Shell irregular, small, seldom exceeding two inches in length; lower valve extensively applied to rocks, with a deep cavity extending under the hinge line, growing upwards, plaited, plaits radially arranged and deep; margins of the lower valve with characteristic spout-like processes; upper valve small and flat; no denticulations; muscle scar generally dark purple.

Reeve (1878) states that it is difficult to distinguish this species from *cucullata* if indeed they be not identical.

Distribution in Indian region

Found on rocks around Karachi.

Crassostrea(?) belcheri (Sowerby)

Description

"Shell very large, compressed, spatulate, rather thick, elognated, foliaceous, with large purplish green scales, lower valve flat; upper convex; hinge broad, ventral margin expanded." –Reeve (1878); after Awati and Rai (*loc. cit.*).

Crassostrea (?) quercina (Sowerby)

Shell small, with undulations, dirty purple in colour, with lines of growth; lower valve flat, thin; upper valve same as the lower but slightly concave; inner surface polished, with big patches of green colour; margins purple or brown; small denticles on the margin near the hinge area; muscle scar circular, large and conspicuous, centrally placed, of a green colour.

Distribution in Indian region

Found attached to shells of other oysters near about Karachi.

Utilization

Oysters are utilized only to a limited extent in India. In our country the oysters are cooked in ghee or vegetable oil after mixing salt and condiments. Only in some places on the west coast people know about the nutritious shellfish and eat them. But for this, only poor people usually fishermen consume them. The massive shells of the oysters are collected in large quantities and sold to lime kiln owners who convert them into lime which is a valuable commercial product being used for whitewashing. In western countries where the oysters are greatly relished, oysters are eaten raw and in a variety of forms like oyster stew, smoked oysters, oyster meat canned in salad oil, oyster meat boiled in wine, breaded oysters etc.

Oyster production

Statistics are not available about the quantity of oysters harvested in India. The total quantity may be small. Oysters have always been an important food resource for the world population (Shaw, 1969). The total world production of oysters was 639,000 tonnes in 1958 (F.A.O., 1969a) and there had been an increase in the annual production in recent years. The average annual production in the period 1964–69 was 793,000 tonnes and production in 1969 was 760,000 tonnes. The world's leading oyster producer is United States of America (production 355,400 tonnes in 1968) followed by Japan (245,500 tonnes), France (39,500 tonnes), Korea (33,200 tonnes), Mexico (42,400 tonnes) and China (Taiwan) (11,700 tonnes). Other important oyster harvesting countries are Australia (7,500 tonnes), Canada (5,500 tonnes) and United Kingdom (200 tonnes). There is a good potential for increasing oyster production of India by culturing the different species that abound our coasts.

III EDIBLE BIVALVES : CLAMS AND OTHERS

K. Nagappan Nayar and S. Mahadevan

Clams belonging to a number of species and a few other edible bivalves occur in appreciable quantities in different parts of the Indian coasts and support subsistence fisheries. Thousands of square kilometres of our coastal seas, backwaters and estuaries form ideal habitat for the growth of these bivalves and many among the poorer classes of the coastal population use them as food although it should be admitted that a vast majority of other fish-eating population of our country have not developed a liking for these shellfish. The flesh of clams being rich in glycogen, protein and health giving minerals is highly nutritious.

In spite of the availability of substantial edible clam resources along the Indian coasts very little attention has been paid to clam fisheries. Hornell (1916d) who made a detailed study of the utilization of shells for manufacturing lime was the first to draw attention to the importance of the clam resources of the Madras Presidency. He (1917) recorded that the clam *Meretrix casta* formed a most important food mollusc. Rai (1932, 1933) showed that *Meretrix meretrix* was the species of prime fishery importance among bivalves of the Bombay coast. Rao (1941) has stated that the clams and mussels are perhaps a more important element in the shellfish populations of our coasts than oysters and that the back-water clams form the basis of a more important fishing industry than sea clams. Recent studies worthy of mention in this context are those of Rao (1951, 1958), Abraham (1953), Nayar (1955), Rao *et al.* (1962), Ranade (1964), Alagarswami (1966), Alagarswami and Narasimham (1968) and Narasimham (1969).

Clams

Meretrix spp.

The clams belonging to the genus *Meretrix* are distinguishable by their thick, triangularly ovate shell which sometimes possesses faint concentric striae. The hinge area is thick and has three grooved cardinal teeth. The pallial sinus is feebly developed. There are three species, *M. meretrix*, *M. casta* and *M. casta* var. *ovum* which are of commercial importance. The first is distributed on both coasts, the second is restricted to the east coast and the third is confined to the west coast. From Bombay on the west coast to Orissa on the east coast one or

the other of these clams is found in fair abundance in muddy sand in estuaries and backwaters wherever the water remains saline all round the year.

MERETRIX MERETRIX (Linnaeus)

This is a large clam with a thick shell and grows to a length of about 75 mm. The periostracum is thin, delicate and of grey or straw colour. On the postero-dorsal margin of the shell a greyish blue or bluish brown band is present (Fig. 3 A).

This species is found at the mouths of the majority of estuaries on the east cost especially those of Adyar, Courtalayar, Vellar and Cooum in Tamil Nadu. It is also found in Pulicat Lake and Chilka Lake on the seaward side. In the west coast it is common in Tellicherry coastal area along the Malabar coast and in river mouths in south Kanara. In north Kanara and Bombay coast the innumerable creeks and vast stretches of estuaries and backwater areas are suited for extensive beds of this clam particularly Bhatya creek, Kalbadevi creek, Myria Bay, Mahaluxmi creek and Mahim creek. Rich beds exist in Bombay, Alibagh, Ratnagiri, Jaytapur and a number of places in north Kanara, of which Karwar (Kali river mouth), Kodibag, Ankola, Tadri (Aghanasini river mouth), Moorba, Wadgoni, Mirgan, Harwada, Mudgian and Sanikatta are important.

According to Hornell (1922b) the clam spawns about the beginning of September and again in May in the east coast. The spawning period varies in different places depending on the physical and chemical properties of the surrounding water. Rai (1932) observed that the principal breeding season of *Meretrix* on the Bombay coast lasts from March to June and with favourable weather it may continue to breed throughout the year except during the monsoon season.

The flesh of the clams is tasty before the bivalves spawn and the fisherfolk exploit the clams at this stage indiscriminately. Naturally people engaged in the collection of clams as well as the local public acquainted with the beds for a number of years in the past, complain that the beds have considerably dwindled in the course of the last ten years. A woman toiling hard for 2 to 4 hours a day may collect about 300 clams from a good bed. The flesh is not commonly sold but used for domestic consumption. The cost of a hundred clams is about 20 paisae.

MERETRIX CASTA (Chemnitz)

COMMON NAME

Tamil – *Matti*

This clam has a thick, moderately large shell with a brown horny periostracum. A dark greyish band is present at the posterior margin of the shell (Fig. 3 B).

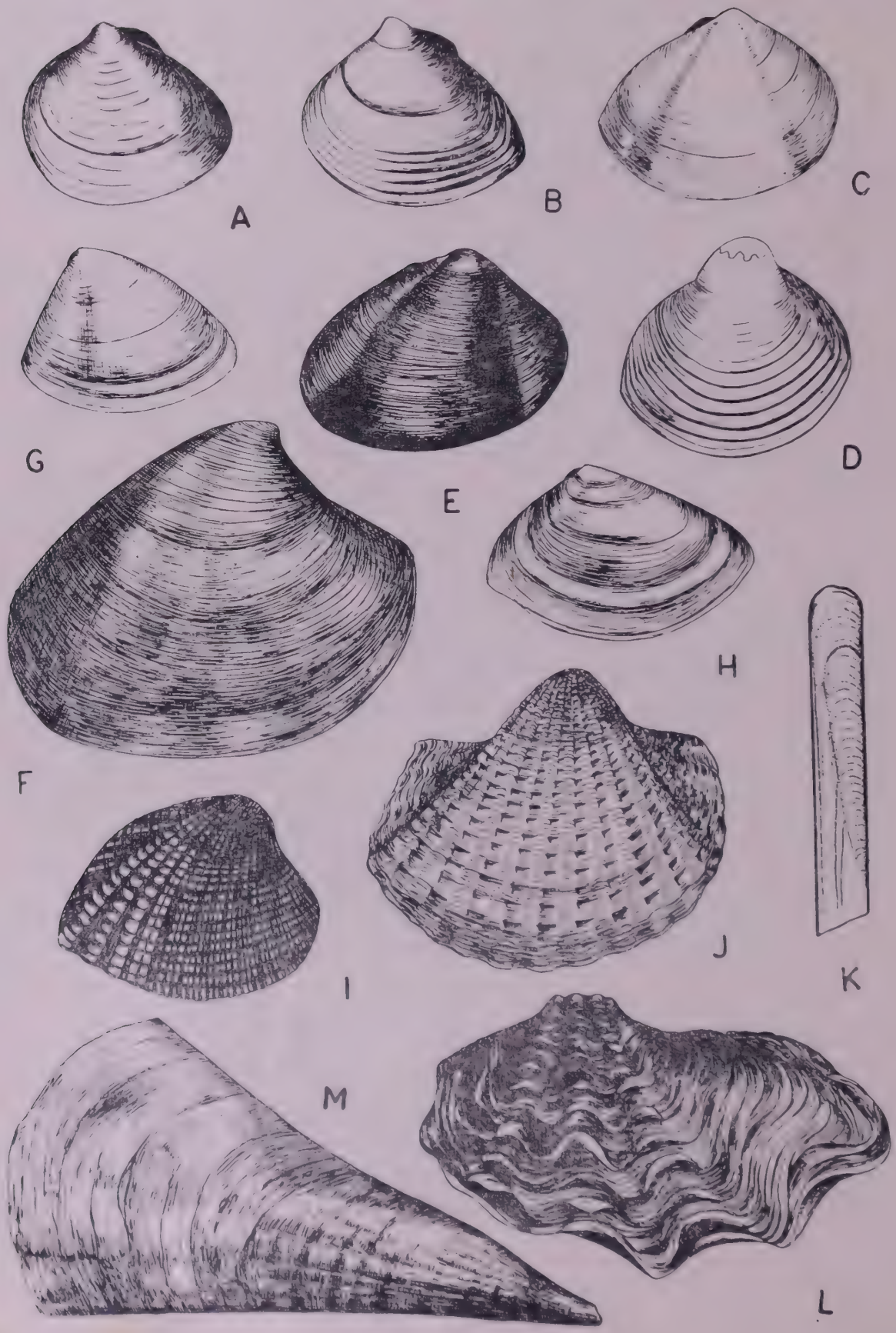

Fig. 3

Rich beds of this species are known to exist in Pulicat Lake, Ennore backwaters, Adyar estuary, Vellar estuary, Athankarai estuary and Pinnakayal estuary on the east coast.

The clam reaches a length of 48.7 mm and a breadth of 38.7 mm in about 18 months. Growth is retarded at least twice in a year (Abraham, 1953). There is greater growth in backwater areas than in rivers. The species attains a size of 56.5 mm in length in about three years but nearly 90% of the clams are fished before they reach a size of 30 mm.

This clam breeds throughout the year in the backwaters but the reproductive activity is at its peak in July–August, in October–November and for a third time in the summer months of March-April (Abraham, *loc. cit.*) in Adyar estuary. In the river areas peak breeding is in summer months and again in September – November. Hornell (1922b) stated that spawning in *M. casta* appeared to take place twice in a year during April–May and in September. In the marine fish farm at Mandapam breeding was recorded in *M. casta* in all periods of the year except for a break in late summer which was attributed to unfavourable conditions (Durve, 1964). The species is known to attain sexual maturity when one month old and the length is 11 mm (Abraham *loc. cit.*). A change in the form of the shell of *M. casta* during growth has been observed by Durve and Dharmaraja (1969).

Silas and Alagarwami (1967) have observed that *Pinnotheres* sp. infests *Meretrix casta* at Malpe and reported that the pea-crab causes damage to the gills, mantle, digestive gland and gonad of the clams.

The percentage edibility of *Meretrix casta* of Ennore backwaters has been found to vary between 7.62 and 17.72 (Venkataraman and Chari, 1951) while in Mandapam marine fish farm it was low being 4.22 – 6.46 (Durve, *loc. cit.*). Venkataraman and Chari (*loc. cit.*) have investigated the seasonal changes in the chemical composition of this species (Table V). The data show that the clams contain good amount of protein and minerals. The fat content is less compared to that of oysters. Kasinathan (1963, 1964a, 1967) had studied the carbohydrate metabolism of this species. Injection of insulin lowered the blood glucose level initially but there was recovery later. Injection of insulin resulted in increase in glycogen content of digestive diverticula and foot. The latter appeared to be a stable storehouse of carbohydrate with some mechanism of

Fig. 3. A. *Meretrix meretrix* (Linnaeus). B. *Meretrix casta* (Chemnitz). C. *Meretrix casta* var. *ovum* (Hanley). D. *Villorita cyprinoides* var. *cochinensis* Hanley. E. *Tellina pinguis* Hanley. F. *Katelysia opima* (Gmelin). G. *Donax cuneatus* Linnaeus. H. *Donax faba* Gmelin. I. *Gafrarium tumidum* Roding. J. *Anadara granosa* (Linnaeus) K. *Solen kempi* Preston. L. *Tridacna maxima* Roding. M. *Pinna bicolor* Gmelin.

TABLE V

Seasonal changes in chemical composition of *Meretrix casta* of Ennore backwaters (after Venkataraman and Chari, 1951)

Months	Edibility %	Water %	Protein %	Fat %	Ash %	P_2O_5 %	CaO %	Iron mg %	Copper mg %
January, 1950	9·71	78·23	9·71	0·69	2·15	0·294	0·496	...	0·52
February	9·92	84·02	10·20	0·81	2·01	0·288	0·237	3·45	1·56
March	8·11	74·42	11·93	0·97	1·76	0·385	0·455	...	...
April	10·81	79·28	10·46	0·84	1·70	0·275	0·173	1·42	0·26
May	7·62	78·59	10·96	1·10	2·31	0·360	0·185	7·65	0·83
June	10·30	75·77	12·29	0·94	1·76	0·356	0·159	13·89	1·97
July	8·10	75·34	11·24	0·86	1·73	0·341	0·184	14·29	1·92
August	10·00	80·00	9·11	1·07	1·12	0·284	0·256	16·56	traces
September	10·33	76·53	10·09	1·03	1·14	0·257	0·156	8·79	0·39
October	15·01	75·48	8·08	0·72	0·67	0·316	0·118	3·95	0·56
November	15·06	76·28	7·98	0·57	0·97	0·291	0·142	7·67	0·94
December	15·75	74·92	9·89	0·63	1·51	0·322	0·169	...	...

regulation. The saponification value of male clams has been found to be higher than that of females and iodine number of fat of females higher than that of males (Kasinathan, 1964 b).

Fishery

Fishing is done almost throughout the year. But the summer months are most convenient for good fishing. It is a common sight to see fisherwomen and girls going about collecting the clams from Adyar estuary, Ennore estuary and Pulicat Lake during low tide. From time to time as they gather the clams, they pile them in heaps on the adjacent sand or mud bank. When they stop fishing they smash the clams one by one with granite stones. The meat is scooped out with the thumb and put in an earthen pot. The shells are left behind and only the flesh is taken home. A woman may collect about 300–400 clams a day. In some cases where the bed is dense the catch may range from 2000–3000 per individual and these are collected and taken home in baskets. The clams are kept as such for two or three days, to be opened as and when required. The clams are not sold in markets regularly though it is not uncommon to see people purchasing clam meat from fishing hamlets when they want. There is no standard price for the meat. It is generally sold on barter system for commodities like sweets, paddy or other grains or pulses. The price ranges between 30 and 50 paisae for 100 clams. Poorer fisherfolk along the coastal areas of Madras, Chingleput, South Arcot and Ramnad fish this species of clam. In spite of indiscriminate fishing these clams are found in fair density because of the rapid rate of growth in the younger stages, the early attainment of sexual maturity and tolerance of a wide range of salinity.

Meretrix casta var. ovum (Hanley)

This clam can be distinguished from *M. casta* by its more elongated shell (Fig. 3 C). The shell is sub-equilateral, covered with a thin, greyish-yellow periostracum and with or without narrow brown bands radiating from the hinge region. The posterior margin is stained greenish grey.

This clam is generally separated as a distinct species. It occurs in great abundance in west coast backwaters. The clams grow to a size of 35-40 mm in length and 25-28 mm in breadth. This clam also is fished indiscriminately. This is one of the important clams of the Kerala State. The flesh is tender and has good flavour. On the Malabar coast the poorer classes of fishermen search for these clams when the general fishing is dull. Men, women and lads go about in small canoes in the backwaters and when a good fishing area is found they anchor the boat, get down into the shallow water, locate the clams with their feet and dislodge them from loose mud. If the area happens to be a little deeper the fishermen dive and gather the clams.

Villorita cyprinoides (Gray)

This black-clam called in Malayalam as *kar erunthee* is a small thick-walled one found only in the west coast estuarine backwaters. This species cannot withstand high salinity. It is usually found in vast beds near the farthest ends of the backwaters where the salinity is lower than 15‰. This clam is said to burrow deep into the soil to escape adverse conditions when the salinity rises above 15‰ during summer months. The distribution does not extend to the vicinity of harbour areas or the sea mouth. But *V. cyprinoides* var. *cochinensis* (Hanley) (Fig. 3 D) is capable of tolerating a wide range of salinity upto 34‰ and therefore found in parts of backwaters near the bar mouth in sand and silt deposits although exclusive silt deposited areas are avoided by this clam (Cherian, 1968).

The clams are fished by the same people who eat *Meretrix*. The shell seldom exceeds 40 mm in length. Nothing is known about the biology of this clam.

Tellina pinguis Hanley

The shell of this species is ovate and moderately large. The pallial sinus is large and deep (Fig. 3 E).

This is one of the most important commercial clams on the Bombay coast. It is a brackish water clam found from Bombay to the south along the west coast. It is found at a depth of one to three fathoms in sandy bottom and also in areas where there is admixture of mud (Rai, 1932). Small numbers of this clam occur in the vicinity of Cochin harbour (Cherian, 1968).

Katelysia opima (Gmelin)

In this species the shell is thick, inflated, smooth and of yellowish brown colour (Fig. 3 F). The inner surface of the valves is white and the pallial line deeply sinuate.

This clam is found in great abundance along the estuaries and backwaters of South India and is called *vazhukku matti* in Tamil. It is next in importance to *M. casta* on the east coast especially in Adyar estuary.

The clam prefers water edge near the river-mouth since it is essentially a marine form. It is found burrowing in quiet shallows as in the mud-flats of Pamban in the Gulf of Mannar and Ratnagiri coast. It has also successfully invaded the estuaries and backwaters where it is found near the river-mouths in Bombay, north Kanara and Madras coasts. It is never found up the river-mouths or in the interior of the backwaters where the salinity is low, a striking contrast to *Villorita cyprinoides* and *M. casta*.

The life span is about three years. Clams of the size 26–33.8 mm in length are over one year old but not completed second year. Similarly 38.8 to 4.35 mm size represents two year old clams. The first definite indication of sexual maturity is seen in three months old clams when they are 11–12 mm in length. In the Adyar estuary growth appears to be restricted to the period from January to July and arrested between August and December when there is a fall in salinity. The clams have been found to spawn thrice in their life span. Spawning starts in December when the estuary is in communication with the sea and lasts about a month (Rao, 1951 b).

The clam beds are extensive in Adyar river-mouth in the east coast and Batya creek and Kalbadevi creek in Ratnagiri where there is a good fishery. Elsewhere along the east coast and west coast it is found separately along the tidal flats and does not form regular fishery.

The clams are fished by fisher-folk along with other clams and the commercial catch does not seem to be composed of any particular size, being there no restriction on size limit in fishery. Fishing is indiscriminate as it exists to-day.

Paphia Spp.

Paphia malabarica, *P. textile* and *P. marmorata* are the common species exploited. In *P. malabarica* the shell is triangularly ovate, the anterior and posterior margins are narrowly rounded and the surface of the shell has well-developed concentric ridges. *P. textile* is characterized by an elongate shell with the anterior and posterior margins rounded and the outer surface is smooth, of pale yellowish white colour and marked with pale purplish grey inverted V-shaped markings.

There is a good fishery of *Paphia* spp. in Karwar and north Kanara river-mouths. The clams occur in depths of up to 4 metres in sandy mud and are called *chippe kallu* in Kannada and *tisre* in Konkani. During low tide fishermen take small scoop nets in one hand against the current and the clams are pushed into the net with the other hand. Information gathered from fishermen shows that during the full moon and new moon days better quantities of clams are collected.

The fishery extends throughout the year with a peak between January and July. In January the fishery is supported by younger ones and in May-July by adults. After the monsoon the flesh is said to be not tasty. During peak fishing each individual collects about 40 kg per day and about 1000 kg are landed daily in each centre (personal communication from Dr. Anthony Raja).

Donax Spp.

Of the several species of the genus *Donax* that occur on the east and west coasts in the surf beaten sands *Donax cuneatus* Linnaeus to a very large extent, and *D. faba* Gmelin and *D. scortum* Linnaeus to some extent are valuable as edible bivalves. At present there is no regular fishery for these clams for food or any organised lime making industry with the result that these valuable resources are neglected. Nayar (1955) and Alagarswami (1966) have studied the biology of *Donax cuneatus* and *D. faba* respectively which abound in the sandy beaches of the southeast coast of India. The clams occur in the surf line along the shore and their presence is revealed by a pair of openings formed by the siphons of each of the clams on the wet sands. The receding waves often dislodge the clams out of the sand. Then they rapidly burrow into the sand. The clams are usually collected by girls and lads who turn over the wet sand with their feet as each roller spends its force and slips back into the sea, and collect in their hands a good number of the clams.

D. cuneatus Linnaeus

Common names

Tamil – *Mural, Vazhi matti*

In this clam the shell is trigonal, inequilateral and has a curved keel extending from the umbo to the postero-ventral corner; there are sharp concentric and finer radiating ones which are conspicuous in the anterior and posterior regions only. The anterior end of the shell is broad and rounded while the posterior end is narrow and rounded; the pallial sinus is deep. The shell is white suffused with pale violet especially towards umbo and the posterior region where the colour is darker. The inner surface of the valves is of deep violet colour (Fig. 3 G).

D, cuneatus grows upto 19 mm in length and its life span is two years. A maximum size of 13–14 mm is attained in 11 months. Sexual maturity is attained when the clams are 10 months old and 10–13 mm in length. The clams spawn for the first time when they are one year old and do not spawn more than twice in their life time. The spawning season is from January to April in Palk Bay (Nayar *loc. cit.*) while at Madras it is more extended, beginning in December and continuing till June (Rao, 1967).

D. faba Gmelin

The shell of this species is ovate with fine concentric striae. There is no keel extending between the umbo and the posterior margin. The ventral margin bears a slight indentation at the posterior end; pallial sinus moderately deep.

Colour pattern variable. The outer surface is pale bluish grey or greyish blue with greyish concentric bands, rays or patches of brown colour (Fig. 3 H).

This species grows to a length of 19.5 mm in the first year and 23.5 mm at the end of the second year. The life span does not appear to exceed three years. The clams reach sexual maturity when they are 13-14 mm in length and have a prolonged breeding period extending from November to June with two spawning peaks, in November–December and May–June (Alagarswami, 1966a).

The above species are collected throughout the year.

Mesoderma glabratum (Lamarck)

Common name

Tamil – *Kakkamatti*

The shell of this species is thick, inequilateral and approximately trigonal in shape. The surface of the shell has closely set, well developed concentric striae. The umbo is small and the hinge bears two cardinal teeth and there is an anterior lateral tooth The pallial sinus is small and angular.

This bivalve is common in the sands of the islands of the Gulf of Mannar. It grows up to 35 mm in length. It is fished and eaten along with other clams.

Gafrarium tumidum Roding

The shell of this bivalve is thick, strongly inflated and sculptured with thick, nodular radial ribs which tend to bifurcate towards the ventral margin. In the interstitial spaces between some of the main ribs there are secondary rows of nodules between the ventral margin and the middle of the surface. The pallial line is entire. The outer surface is white with irregular dark spots posteriorly and near the umbo (Fig. 3 I).

This is a cockle clam of considerable importance and is called *vari matti* along the southeast coast of India particularly in Palk Bay area. Along the Gulf of Mannar the mud-flats are rich grounds for this clam. Along the northern parts of the Coromandal coast and the west coast this species is very scarce. It inhabits the muddy sand near the low tide level on the open coast. The flesh is tender and is liked by fisherfolk who collect them during spring tides. The clam grows to a length of 45 mm and is said to spawn in the period September—October.

Three other species of *Gafrarium* are represented on the Indian coasts in restricted numbers, *G. dispar* at Pamban, Kundugal Point, Krusadai Islands and in Palk Bay, *G. pectinatum* (Linnaeus) in Pamban, Kundugal Point, Krusadai

and Shingle Islands and in Palk Bay and *G. divaricata* (Chemnitz) at Madras and Shingle Island. *Circe scripta* (Linnaeus) another cockle clam found sparsely distributed along with *G. tumidum* is also collected and eaten.

The true cockles are represented in Indian coasts by several large and handsome species chiefly *Cardium asiaticum* Bruguiere, a sandy coast inhabitant. The cockles are not commercially important as they do not appear to occur in thickly populated beds.

RAZOR SHELLS

The ark-shells *Arca tortuosa* Linnaeus and *A. inequivalvis* Bruguiere are marine species common in Palk Bay on the east coast where beds exist on a bottom of dirty muddy sand at depths upto ten metres. But the meat is not appreciated by the fisherfolk and therefore the bivalves are not exploited for the meat. Narasimham (1969) has studied the biology and fishery of *Anadara granosa* (Fig. 3 J) which is commercially important on the Kakinada coast. The ark shells are fished from 4 metres depth by fishermen who use them almost entirely for manufacture of lime. *A. granosa* grows to a length of 31.5 mm at the end of the first year and 49.5 mm at the end of the second year. The species appears to breed throughout the year in Kakinada Bay with peak spawning activity between January and April. *Arca* (*Anadara*) *granosa* has been reported by Hornell (1922b) and Rao (1941) to occur in the sandy backwaters of the east coast especially in Pulicat Lake. The meat of this cockle is tough and red and believed to be nutritious. The ark-shells are widely cultivated in Japan but they are not appreciated much by Indian people.

RAZOR CLAMS

The scabbard-shaped razor clams belonging to the genus *Solen* occur on sandy tidal flats where they live at depths of 2 cm to 20 cm below the surface at the low tide mark as well as in deeper waters. These clams do not form a regular fishery anywhere on our coasts except on the Ratnagiri coast. Rao *et. al.* (1962) have described the taxonomy and distribution of *Solen* spp. and studied the biology and fishery of the commercially important *S. kempi* Preston of Ratnagiri.

Solen kempi Preston

The shell is small, about six times as long as high, periostracum yellowish-brown and glossy; anterior region obliquely truncate, posterior region rounded (Fig. 3 K). Cardinal tooth in right valve with a shallow groove throughout its breadth; dorsal margin of soft body slightly concave in the anterior region and convex in the posterior region; siphon long and segmented; foot long, flattened and about half the length of body.

Solen Kempi occurs in Chilka Lake, Ennore (near Madras) and Ghakkadi (near Ratnagiri).

S. kempi grows rapidly attaining a length of 37.5 mm in 6 months and 47.5–52.5 mm at the end of the first year. The largest size 66 mm is attained when the clams complete second year of their life. Gametogenesis takes place in September and spawning between late October and March. Sexual maturity is attained when the clams are 5 months old but spawning does not take place till they attain the age of one year.

The clam beds are found in regions where there is a good amount of silt deposited by the river enabling the shellfish to thrive well. The habitat is sandy in shallow waters from high water mark to a little beyond the low water mark. The main fishery is from February to May but extends up to September.

In Maharashtra fishing of these clams is done exclusively by women and girls of the community known as *bhandaris*. The clams are fished during low tide. The tell-tale openings of the burrows noticed on the beds during the low tide effecting little jets of water here and there indicate the retreat of the clams to the bottom of their burrows on feeling the vibrations caused by feet upon the flat. It is difficult to dig them out as they burrow and go down quickly. Even if one manages to catch hold of the posterior end it is hard to pull a large individual out. Hence they are dug out of their burrows by means of a broad bladed, strong steel knife which has a pointed free end. The digging is done deftly and in a flash as otherwise the animal will burrow deeper and deeper to escape capture. The catch is used for domestic consumption only and partly as fish bait for long-lining.

GIANT CLAMS

Tridacna maxima Roding

One species of giant clam of the genus *Tridacna, T. maxima* Roding occurs in the Andaman and Laccadive Islands. *T. maxima* is commonly known as *T. elongata* Lamarck but the specific name *maxima* has priority (Rosewater, 1965). In *T. maxima* represented in the Andaman and Laccadive Islands the valves are very inequilateral and the hinge is very much shorter than the ventral margin; primary radial sculpture consists of 6 to 12 broad, moderately convex rib-like folds of which 6 or 7 are very well developed, secondary radial sculpture consists of 10–20 evenly spaced riblets on folds and 3–7 in their narrow interstices; concentric sculpture consists of closely spaced undulate lines which produce low scales on primary folds (Fig. 3 L). The species has a wide distribution from East Africa to Polynesia with the exception of Hawaii. The flesh of *T. maxima* is used for food in the Laccadive and Nicobar Islands. The valves of *Tridacna* are used as benitiers in churches. So the clams are also called holy-water clams.

FAN SHELLS

PINNA BICOLOR Gmelin

Pinna spp. are utilized as food in Japan, Polynesia and other countries in the Indo-Pacific region (Rosewater, 1961). But *Pinna bicolor* Gmelin which occurs in good density at Pamban, Kundugal Point and near Mandapam is not made use of at present.

The shell of *P. bicolor* is broadly to attenuately triangular in shape, posterior margin truncate or convex-rounded, valves heavy and thick or rather thin and fragile; valves translucent and of light horn to dark purplish brown colour, 8 to 17 radiating ribs which are sometimes scarcely visible present. Spines almost absent except in the posterior region, fine concentric growth lines present, dorsal margin straight or slightly convex, interior of valves light smoky horn to dark purplish brown in colour, nacreous area iridescent (Fig. 3 M).

The species lives in sandy mud attached to the substratum by well developed byssus threads at depths of one to two fathoms. While the meat is edible the valves could be carved to form decorative articles.

From the foregoing account it is clear that clams and some other bivalves are sought after by considerable section of poorer classes of fisherfolk as a source of food. However, clams have not found favour with the vast majority of the population. With the prevailing indiscriminate fishing by most of the fishermen there are possibilities of the clam beds becoming depleted. This state of affairs caused by human agency can assume greater dimensions once natural mortality due to sludge deposition on account of floods in rivers, discharge of pollutants into rivers, deposition of ballast mud in the vicinity of the beds and the like also combine to make the ruin complete. As a first step to improve the edible clam fisheries certain aspects warrant our consideration in the interest of the future management of the clam fishery resources of the country.

In India at present there is no comprehensive work on the biology of the various species of clams that are edible except for a few studies mentioned. Investigations on the rate of growth, longevity, size at first maturity, periods of spawning, biotic and abiotic environmental factors influencing growth and breeding and suitability of different species of clams for being used as food that have not already been studied should be started. Resources survey of the area of availability, seasons of fishing, quantity fished and value of the fisheries are all yet to be properly assessed in the different maritime states of our country. These aspects should be given priority in the investigations. Side by side with these studies the edible values of the meat of the different species of clams from different places should also be invetsigated.

So far as the existing well-known clam beds are concerned steps should be initiated to clear the beds especially backwater mud flats, of stones and gravel during the low tide. Ploughing certain areas will enable the clams to burrow quickly in the soil. Restocking them with clams from other beds in the neighbouring localities should also be attempted. Transplantation experiments should also be tried in areas where clams are not available depending on the suitability of the places. Laying out beds for culture, one for seed clams and another for young clams to grow and a third for adult clams to serve as a breeding reserve, observance of short closed season for fishing during peak periods of spawning and elimination of predators and pests from the beds are some of the steps to be undertaken to counter the effects of overfishing and indiscriminate removal of clams.

In countries abroad in spite of enforcing numerous regulations for the conservation of very valuable clam beds they have been found to undergo gradual deterioration. In this context the culture of clams on scientific lines is the only possible solution to solve the problem. The available natural resources also should not be neglected.

IV EDIBLE GASTROPODS

K. S. Sundaram

Marine gastropods form the largest group of species in the phylum Mollusca in shallow seas. Of these only a small number of species are suitable for being utilized as food by man. The univalves are fished in many parts of the world for bait, for their beautiful shells and manufacture of lime. Since the animals are passive, simple methods are used in collecting them.

The edible gastropods limpets, trochids, whelks, the sacred chank (*Xancus pyrum*), olives (*Oliva* spp.), the green snail (*Turbo*) etc. are represented in different regions of the Indian coasts in the intertidal zone and shallow waters. They are fished by fishermen and poor coastal people for food usually when fish are not available. In India the above mentioned edible gastropods are generally collected for their shells which are cleaned, polished and sold as ornamental articles. Gastropods are seldom sold in the markets for being used as food. The button-shell *Umbonium vestiarium* is the only species that finds a place in fish-stalls in Malwan in Maharashtra.

The habits, ecology and economics of the edible gastropods of Indian coasts have been dealt with by Hornell (1917, 1951). Rai (1932), Setna (1933), Rao (1939, 1941) and Rao (1958, 1969) have made contributions on the shell-fish and their fisheries in general and stressed the importance of the shell-fish in the economy of the fishermen. The descriptions of a number of commercial gastropods have been given by Satyamurthi (1952). Rao (1969) has pointed out the non-availability of statistics of molluscan shell-fish production and recommended the survey of molluscan resources, estimation of annual production, studies on the biology of commercially important species and governenmtal control over shell-fish resources.

The following account deals with the eleven important species of edible prosobranch gastropods of Indian coasts belonging to eight genera and seven families. The salient features of the gastropods, their habits and habitats, information available on the life-history and biology of the species, utility and food value are briefly mentioned.

Class	Gastropoda
Subclass	Prosobranchia
Order	Archaeogastropoda
Family	Patellidae

Cellana radiata (Born)

Common name

English – *Limpet*

Tamil – *Unai*

The shell is conical or cup-shaped and the apex is placed more or less in the middle. The inner surface has a pearly lustre; the outer surface is light or dull brown with whitish rays (Fig. 4 A).

The limpets inhabit the intertidal zone, adhering to rocks and feed on the minute algae present on them. They are mainly eaten by the poorer classes of people at Covelong, Tamil Nadu (Hornell, 1917).

Distribution in India

Gulf of Kutch, Cochin, Madras, Mahabalipuram, Gulf of Mannar and Palk Bay.

Family Trochidae

Trochus niloticus Linnaeus

The shell is conical or pagoda-like, white with many reddish-brown longitudinal bands (Fig. 4 B). The mother-of-pearl underlines the shell surface. The shell attains a size of 8 cm to 12 cm and the period of longevity is about ten years. The sexes are separate and cannot be determined externally. The mature gonads are creamy white in males and green in females. Sexual maturity is reached when the animals are between 6 cm and 7 cm in diameter. This is a continuous breeder and intensive breeding activity is noticed during the warmer months.

The food of the species includes brown and green algae. Sharks and rays are the common predators of this large trochid. Boring bivalves (*Lithophaga* spp.) and some gastropods (*Saptadanta nasika* and *Patella*) have been observed to bore into the periostracal and nacreous layers of the shell and damage it (Rao 1936, 1937).

In India *Trochus niloticus* is found in the Andaman Nicobar group of islands. Fishing of the species can be done in the islands only on obtaining licence from the government. The shells are obtained by diving to depths of one to three fathoms. The divers reach the shell beds by means of a kind of dinghy called *sampan*. The flesh of the animal is removed by a sharp pointed instrument resembling a gimlet bent at the end. The anterior portion of the animal mainly

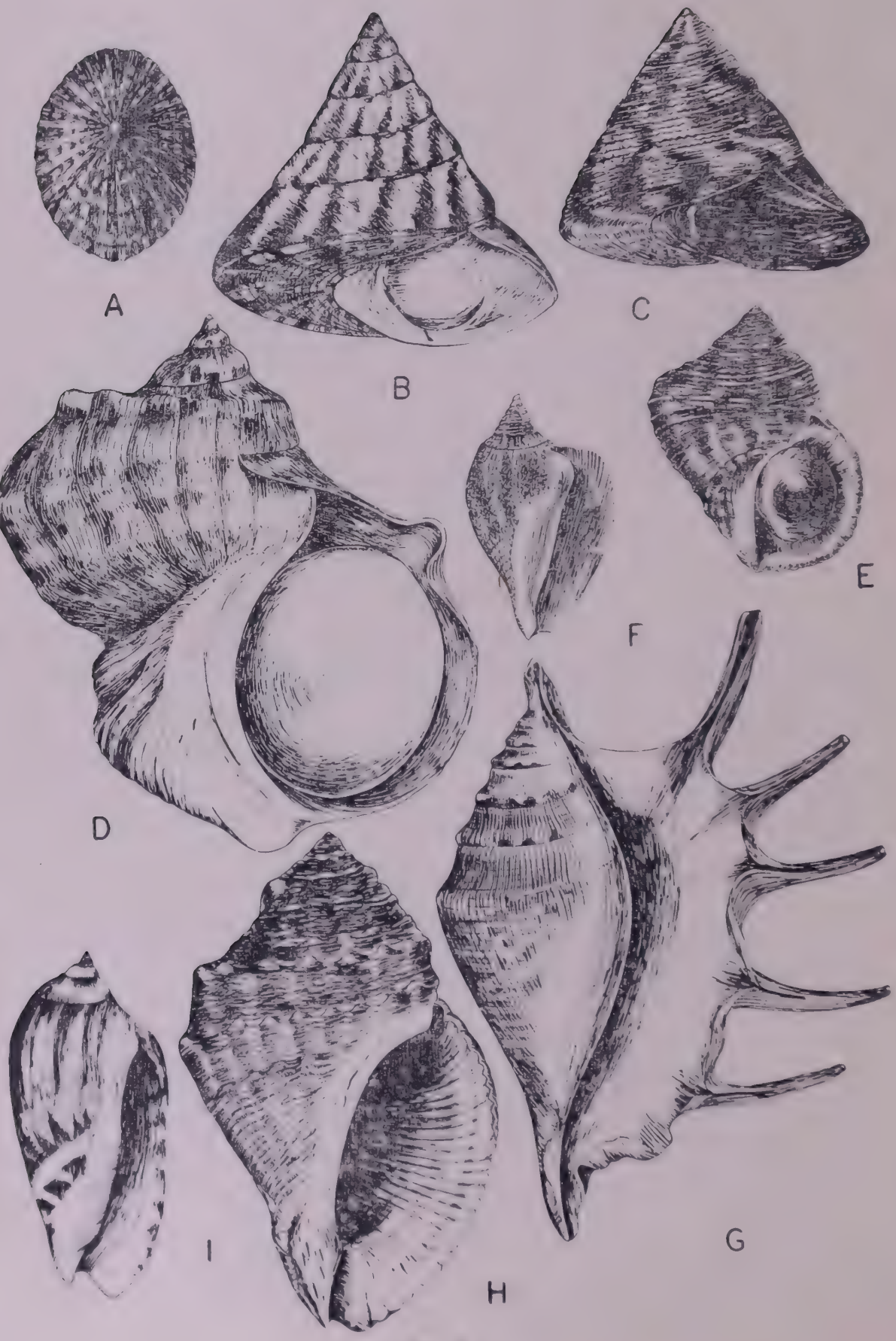

Fig. 4

the foot is boiled, salted and dried for local consumption and export. The shells are used for making buttons and art objects (Rao, 1939, 1941; Setna, 1933; Mukundan, 1968).

DISTRIBUTION

Ceylon, Mergui, Andaman and Nicobar Islands to Samoa, Queensland, Western Australia, New Caledonia, Philippines, Fiji to Japan.

TROCHUS RADIATUS Gmelin

The shell is conical with regular rows of spiral tubercles. The columella is devoid of denticulation. The shell is whitish and marked with transparent reddish bands (Fig. 4 C).

DISTRIBUTION IN INDIA

Gulf of Kutch, Bombay, Gulf of Mannar, Palk Bay, Laccadives and Andamans.

UMBONIUM VESTIARIUM (Linnaeus)

The shell is small and button-like, with highly polished surface, the spire is depressed; the body whorl is broad and flattened and the umbilical callosity large and thick. The general colouration and pattern of colour design of this beautiful button-shell presents a wide range of variation from pale brown or greenish or reddish brown with transpiral wavy lines to white and light pink with spiral bands or fine dark spots (Fig. 19 I).

These univalves are capable of burrowing rapidly in sand with the help of their slender, pointed foot. Hundreds of them can be collected if the sand in the littoral region is dug up.

Large quantities of *Umbonium* are sold at Malwan in Maharashtra in the months of March, April and May. The shellfish are boiled in fresh water and the meat is extracted with the help of a needle and used in curry or soup (Rai, 1932).

DISTRIBUTION IN INDIA

Gujarat, Maharashtra, Goa Gulf of Mannar and Palk Bay.

Fig. 4. A. *Cellana radiata* (Born). B. *Trochus niloticus* Linnaeus. C. *Trochus radiatus* Gmelin. D. *Turbo marmoratus* Linnaeus. E. *Turbo intercostalis* Menke. F. *Strombus canarium* Linnaeus. G. *Lambis lambis* (Linnaeus), H. *Thais rudolphi* (Lamarck). I. *Oliva gibbosa* (Born).

Family Turbinidae

Turbo marmoratus Linnaeus

The giant member of the family commonly called 'green snail', has a thick and massive shell with a wide aperture. The outer surface is dark and mottled with brown and white. The pearly lustre of the shell is clearly visible when the animal and the outer coating are removed. The large and solid operculum protects the animal from predators (Fig. 4 D).

The species is found in the shallow to deeper waters of Andaman and Nicobar Islands and regularly fished from there along with *Trochus niloticus*. The fishery is controlled by the government as in the case of *Trochus*. The animal provides an important food item. The thick and heavy operculum which closes the aperture firmly, is a hindrance to the extraction of the flesh by using same instrument that is used in the extraction of the flesh of *Trochus*. So the animals are kept exposed on the deck of the motor boat for a considerable time and when the animals creep out of the shells they are removed. The foot and the snout of the animal are cut into small pieces, boiled and dried for consumption (Setna 1933; Rao 1939).

Turbo intercostalis Menke

The shell is turban-shaped and thick, and has well-developed spire. The spiral ridges are transpirally grooved. The colour is greenish brown with well-marked yellowish patches (Fig. 4 E).

The species feeds on brown and green argae growing on the rocks or other substratum in the shallow waters. The sexes are separate. From external appearance the sexes cannot be distinguished. This snail is distributed on rocky coastal areas. The island women of Pamban collect these shells during the spring tides from the coral reefs nearby and boil the shellfish to remove the flesh. The flesh extracted in this manner is used in making curry and soup. The flesh of *Turbo* is rich in calcium and iron and compares favourably with that of true fish (Chari and Unny, 1947). The opercula are sold as curios.

Distribution in India

Gulf of Kutch, Gulf of Mannar, Palk Bay, Waltair, Laccadive and Andaman Islands.

Family Strombidae

Strombus canarium Linnaeus

The shell is very much calloused with polished columella and wing-shaped outer lip. Irregular pattern of wavy light brownish lines are present on the

whitish shell. The aperture is glossy (Fig. 4 F). The animal has a strong, muscular foot and at the hind end a claw-like operculum is present. The members of the genus *Strombus* are dioecious and the males possess a long, open, grooved and 'prong-like' penis.

This species like the other members of the family inhabits the sandy and muddy areas in shallow waters and browses on algae. They are very common from the low-tide mark to a depth of six to seven metres.

The poorer classes of people of Ramanathapuram district, Tamil Nadu collect these shells along with other molluscs and cook their flesh (Hornell, 1917).

DISTRIBUTION

Southern India to Australia and Melanesia, and in the north to Japan.

LAMBIS LAMBIS (Linnaeus)

COMMON NAMES

English – *Five-fingered chank*

Tamil – *Aiviral sangu*

The shell is large and heavy and the outer lip is prolonged into digitate processes (Fig. 4 G) which are not conspicuous in the younger forms. The siphonal canal is long and slightly turned to the left side. The columella and the interior of the aperture are smooth and shiny. Aperture is of cream or light rose colour with yellowish tinge. The operculum is long, brown and transparent.

The five fingered chank is found on both the coasts of India but they are abundant in the coastal waters of the southeastern region. The *kadayan* and Muhammedan *bech-de-mer* divers collect these shells from the shallows of Palk Bay between Pamban and Tondi. The shell is broken and the flesh extracted and used in curries. The shells are used as sinkers, as traps for capturing *Octopus* and in the manufacture of fancy articles.

DISTRIBUTION

East Africa to Micronesia and eastern Melanesia

Family Muricidae

THAIS RUDOLPHI (Lamarck)

The shell is thick and spindle-shaped, dark blackish brown in colour and devoid of tubercles. The spire is short and the body whorl is wide with large

aperture. Widely spaced spiral ridges and alternating black and yellowish white patches are distinct. The operculum is horny and oval in shape (Fig. 4 H).

Thais bufo (Lamarck)

This species can be distinguished from the above one by the nature of short spire and the inflated body-whorl. The body-whorl is characterised by widely set tubercles and non-tuberculated and raised spiral ridges. The aperture of the outer lip is thick. . The shell is light brownish yellow.

Distribution in India

Gujarat, Maharashtra, Tamil Nadu.

Thais rudolphi and *T. bufo* are found on rocks or inner surfaces of boulders between tide marks. These rock whelks feed on barnacles and other molluscs, boring through their shells (Hornell, 1951). The breeding period of *Thais bufo* is from January to June. The egg clusters yellow or violet in colour, are found attached on the under-surfaces of boulders or rocks. The egg capsules are like cylindrical tubes with a long stalk and an opening at the top. The sexes in this species are separate; the female is slightly bigger than the male (Chari, 1950). The rock-whelks known as *parattai* in Tamil are eaten by the coastal people of Ramanathapuram and Tirunelveli Districts of Tamil Nadu. On the Bombay and Konkan coasts these species are collected along with other shellfish and the meat is extracted after boiling and cooked (Rai, 1932).

Family Olividae

Oliva gibbosa (Born)

The shell is smooth and shiny with beautiful colour pattern on the outer surface. The spire is very short and the columella is thickened (Fig. 4 I). The mantle lobes meet over the back of the shell and protect the shell from erosive action. The shell is oblong and stout and has a long and narrow aperture. Operculum is absent. The animal is provided with a very large and broad foot with which it ploughs its way through loose muddy sand. The shells can be collected by tracing the long and irregular trail they leave behind while moving and also by the siphon and tentacles which protrude out of the sand.

The handsome olive is represented in the sandy areas in the intertidal and sub-tidal zone on the east coast of India. They can be collected in good numbers between February and April. On the Coromandal coast the olives called *kovanji* in Tamil are collected by *pattanawar* (fishermen caste) women and children during February and April. The flesh is extracted after boiling the animal in fresh water. The meat is consumed by making curry or frying in oil (Hornell, 1951).

Family Vasidae

XANCUS PYRUM (Linnaeus)

COMMON NAMES

English – *Sacred chank*
Tamil – *Sangu; Palsangu*
Telugu – *Sankham*
Hindi – *Sankh*

The shell is large, thick, pear–shaped and covered with a brownish horny periostracum. The spire is high and apex pointed. The whorls have slightly angulated shoulders; the one on the body whorl is distinct. The shoulder ridges bear a series of small, compressed tubercles. The columella is thickened with callus and bears four transverse folds. The anterior canal is wide open. When the periostracum is removed the shell is ivory white (Pl. III A).

DISTRIBUTION IN INDIAN REGION

Gulf of Kutch, Kerala, Gulf of Mannar, Palk Bay, and up to mouth of Godavari, Andamans, Ceylon.

Male chanks attain sexual maturity when they are 57 mm to 60 mm in diameter. The female is usually larger than the males. Fertilization is internal and the fertilized ova are deposited in a spirally twisted chitinous capsule known as 'ram's horn' (Hornell, 1914). Each egg capsule contains 28 to 36 eggs within it. The young ones are characterized by a spirally coiled shell and well-developed velum and foot (Natarajan, 1957). A free-swimming larval stage is absent. The young, about one cm in length, eat out portions of the chambers of the soft and pliable capsule and force their way out.

The sacred chank usually inhabits fine or soft sandy areas or *poochi manal* (Tamil) richly infested with polychaete worms which constitute their main food item. They are fished from the Gulf of Mannar and Palk Bay and the industry is controlled by the government.

The *parawa* chank divers of Tuticorin have started using the flesh of this gastropod as a food item in large quantities since the famine of 1877. Now it has become a common food item of the people living in Tirunelveli and Ramanathapuram districts of Tamil Nadu where there are important chank fisheries. On Tuticorin coast the chank grounds are 8–12 miles from shore, where the depth is 7–12 fathoms. Fishing is done by skin diving between November and May when the water is clear (Nagappan Nayar and Mahadevan, 1967). The chank divers remove the foot and the head region from the shell with the help of an iron skewer. The muscular tissue commonly called *sangu sathai* in Tamil thus

extracted is boiled in water with a small amount of salt, cooled, cut into slices and sun-dried for two or three days. The chank flesh chips are stored in air-tight containers for use later. The chips are consumed by frying in oil and are considered a delicacy by the fishermen. The *pattanawars* of Pulicat fishing village fish the chank with *thuri valai* and eat the flesh after boiling. Chank flesh chips are rich in protein and minerals (Venkataraman and Chari, 1953) and can be used as a substitute for fish.

While in India the value of the edible gastropods as food is not realized by most people, in other countries the edible gastropods are very much relished. Snails and olives have been special items of dinner even at the time of Pliny the the younger (Cook, 1895). The periwinkles (*Littorina*) that are abundant between tide marks are gathered in large quantities in United Kingdom, United States of America and Ireland and eaten after boiling (Russel and Yonge, 1963). The abalones which are said to have delicate flavour are caught in large quantities annually in Mexico (6,900 tonnes in 1969), United States of America (1,600 tonnes) and Japan (6,500 tonnes) and in lesser quantities in Canada, South Africa, Taiwan, Korea and Australia (F. A. O., 1970a). The edible whelks (*Buccinum* spp., *Busycon*), trochids and strombids are captured in large quantities in Japan (8,500 tonnes), Chile (3,600 tonnes), U. K. (2,100 tonnes), Korea (2,600 tonnes) and Malaysia (500 tonnes). Whelk steaks are prepared by slicing the foot and body into pieces 1 cm thick and pounded between two pieces of cheese cloth with a hammer. The steaks are seasoned with black pepper and salt, rolled in flour, fried and served hot in the Bahamas and other islands of the West Indies (Zinn, 1970). The flesh of some species of univalves such as *Lambis* is said to have narcotic effect (Abbott, 1961).

The extent of edible gastopod resources belonging to different genera in the various parts of the country's coasts should be determined and steps taken to protect the resources from indiscriminate removal. There is need for information on the optium level of fishing that could be allowed. Investigations should be conducted to study the biology of the chank *Xancus pyrum* and to find out the possibility of increasing its production by the discovery of new grounds of occurrence.

V CEPHALOPODS

R. Sarvesan

The cephalopods (squids, cuttlefish and octopi) are exclusively marine molluscs. These are commercially important and are fished in large quantities in several countries. The average annual world catch of cephalopods during the period 1963-1969 was 901 thousand tonnes which is about 30% of the average total world mollusc production of 2,971 thousand tonnes for the same period (Table VI). Represented by over 650 species (Choe, 1966), cephalopods occur in all the oceans of the world, and are distributed from shallow inshore areas to deep oceanic waters. They widely range in size from tiny sepiolids to giants like *Architeuthis* sp. which grow to a size of over 60 feet in total length. They provide food for man and form part of the diet of animals such as whales, seals, oceanic birds and certain valuable food fishes.

Cephalopods are caught in seas around India in fair quantities, but largely incidentally in nets that are operated for other commercial fishes, almost all through the year. Several species have been reported but to mention a few of the commonly occuring cephalopods are *Sepia pharaonis* Ehrenberg, *S. aculeata* Ferussac & d'Orbigny, *S. thurstoni* Adam & Rees, *S. brevimana* Steenstrup and *Sepiella inermis* (Ferussac & d'Orbigny) among cuttlefish, *Sepioteuthis arctipinnis* Gould, *Loligo duvauceli* d'Orbigny, *Loligo hardwickii*, *Loliolus investigatoris* Goodrich and *Euprymna stenodactyla* Grant among squids and *Octopus dollfusi* Robson, *O. rugosus* (Bosc), *O. globosus* Appellöf, *O. herdmani* Hoyle and *O. hongkongensis* Hoyle among octopi (Rao, 1958; Silas, 1968).

At the present time utilization of cephalopods as food is very limited in India. Only the coastal dwelling people have taken advantage of these nutritious items and the people of interior places are not much familiar with the shellfish. Our annual average cephalopod catch for the period 1959 to 1969 is estimated to be only 523 tonnes. This figure appears to be far below the exploitable resources of our seas. Apart from the above listed common littoral species, the recent exploratory surveys and planktological investigations conducted off the west coast and in the Laccadive sea have brought to light the availability and distribution of many potentially important oceanic squids and cuttlefish (Silas 1968, 1969; Silas and Sarvesan, 1968). The oceanic squids constitute the hitherto untapped resources of the seas around India. They are chiefly members of the family Ommastrephidae, the most important of them being *Symplectoteuthis oualaniensis* (Lesson) which is abundantly distributed in the northern and central parts of the Indian Ocean (Filippova, 1968).

TABLE VI

World catches of marine invertebrates for the period 1963 to 1969. Figures indicate landings of live weight in thousand tonnes (Source: F. A. O. 1969a, 1970a).

Years	Crustaceans, molluscs and other invertebrates.	All molluscs	Cephalopods	Cephalopod catches expressed as percentages of total molluscan catches
1963	4090	2924	959	32.8
1964	3847	2646	624	23.6
1965	4049	2830	844	29.8
1966	4219	2911	824	28.3
1967	4456	3065	938	30.6
1968	4761	3325	1168	35.1
1969	4535	3101	950	30.6
Average	4279	2971	901	30.3

There are a few works available on the systematics of Indian cephalopods in which technical descriptions of all the common species are found (Goodrich, 1896; Massy, 1916; Adam, 1938 and 1939, Adam and Rees, 1966; Gravely, 1941; Satyamurti, 1956). Key to the field identification of the different genera of cephalopods to which the common species belong is given below. The external and the more familiar internal characters are utilized for distinguishing them.

1. Cephalopods with eight circumoral arms, without tentacles; arm suckers arranged in two rows, without horny rings and stalks. Third arm tip of male spoon-shaped (hectocotylized) ..... (Octopodidae) *Octopus*.

   Cephalopods with ten arms eight being short and circumoral and two slender and tentacular. Suckers of the arms and tentacles stalked and equipped with armature. 2

2. Shell (cuttlebone) internal calcareous in nature, body ovoid and dorso-ventrally somewhat flattened. Fins narrow, marginal in position and extending on either side along the entire length of the mantle, not uniting at the end. Arms with mostly quadriserial suckers ... (Sepiidae) 3

   Shell (gladius or pen) internal but chitinous in nature. Body cylindrically elongate. Fins either terminal or marginal in position uniting at the apex of the mantle 4

3. Cuttlebone broadly oval in shape and with a spine at the posterior end. The mantle without a glandular pore at the posterior extremity ..... *Sepia* (*S aculeata* Fig. 7 A and *S. pharaonis* Fig. 6 A)

   Cuttlebone smaller in size, oval in shape and devoid of the spine. The mantle bears a small but distinct glandular pore at the posterior extremity... *Sepiella* (*Sepiella inermis* Fig. 7 C, D, E)

4. Fins triangular or rhomboidal in shape, restricted to the posterior margin of the mantle.....*Loligo* (*Loligo duvauceli* Fig. 5 C)

   Fins broad and extending almost to the entire length of the mantle ..... *Sepioteuthis* (*Sepioteuthis arctipinnis* Fig. 5 A)

COMMERCIALLY IMPORTANT CEPHALOPODS

Very little is known about the fishery and biology of Indian cephalopods. Hornell (1917, 1922 and 1951c) has given a general account of the fishery of Palk Bay squids and octopus in Ramand district in Tamil Nadu. Rao's (1954) work on the biology and fishery of the Palk Bay squid, *Sepioteuthis arctipinnis* is the only detailed study of its kind available on the cephalopods of this country.

SQUIDS

Squids belong to the order Teuthoidea (Decapoda) which includes the majority of cephalopods, possessing a stream-lined soft body with a pair of fins varying in shape, size and disposition. The distinct head in front is with ten circumoral arms provided with toothed suckers or claws or both. An internal shell known as pen or gladius, when present is imbedded in the dorsal mantle skin. The gladius of squids is almost transparent, thin and chitinous in nature. It varies in shape in different species. Squids exhibit enormous power of swimming and their swift progression through water is effected by the combined action of the mantle and the specialized structure called siphon or funnel situated on the ventral side. Such fast moving squids are distributed from shallow to varying depths of all oceans.

SEPIOTEUTHIS ARCTIPINNIS Gould

COMMON NAMES

Tamil–*Ekkikanavai, Kundal kanavai*

Sepioteuthis arctipinnis is a common Indo–Pacific species. In India this is widely distributed but large concentrations are confined to the south–eastern coast especially the Palk Bay and Gulf of Mannar. This particular species is readily distinguished from all other squids by the presence of very wide and long fleshy

fins extending almost the entire length of the mantle and the presence of chitinous pen. The following description of the species and account of its biology is based on the work of Rao (1954).

DESCRIPTION

The mantle is elongate, conico-cylindrical in outline, tapering to a blunt point behind; anterodorsally the mantle extends over the nuchal region into a round point, and anteroventrally below the funnel it bears a deep emargination; fins, attached on either side traversing almost all along the entire length, are large, thick and muscular; the fins are narrow in front, gradually widening behind and broadest about the posterior third of the body beyond which they narrow down rapidly and meet each other at the posterior extremity; head slightly narrower than the body; eyes large and prominent; funnel large, broadest at the base and provided with a valve (Fig. 5 A).

Arms unequal in length in the order 3=4.2.1. the second and third pair of arms are prominently keeled; suckers of all arms are arranged in two alternating rows; the horny rings of the suckers equipped with teeth on their outer margins; In the males the left ventral arm is hectocotylized by the modification of suckers and pedicles of the distal half of the arm. Proximally there are about 20 normal suckers followed by 6 pairs of enlarged pedicles with smaller suckers. Beyond this, on the distal portion of the arm, suckers are absent and the pedicles are enlarged into fleshy conical papillae; dorsal row of pedicles slightly larger than the ventral rows.

Tentacles moderately long and the stalks are slightly laterally compressed; tentacular clubs large and provided with trabeculate protective membranes on the sides. The club suckers are quadriserially arranged, suckers of medial rows larger than those of the margial rows; chitinous rings of the club suckers are denticulate.

Mouth surrounded by seven lappets; the tips of the lappets possess minute suckers with horny rings having about 25 blunt teeth. The gladius is chitinous and lanceolate in shape and colourless (Fig. 5 B). The colour of the animal is whitish in fresh condition with greenish tinge surrounding the eyes. Chromatophores present all over the body excepting the ventral surface of fins. On the dorsal surface of the mantle and fins grey coloured transverse streaks are found which are distinct in males.

Fig. 5. A. *Sepioteuthis arctipinnis* Gould Dorsal view of male. B. Gladius of *S. arctipinnis*. C. *Loligo duvauceli* d' Orbigny Dorsal view of female. D. Gladius of *L. duvauceli*.

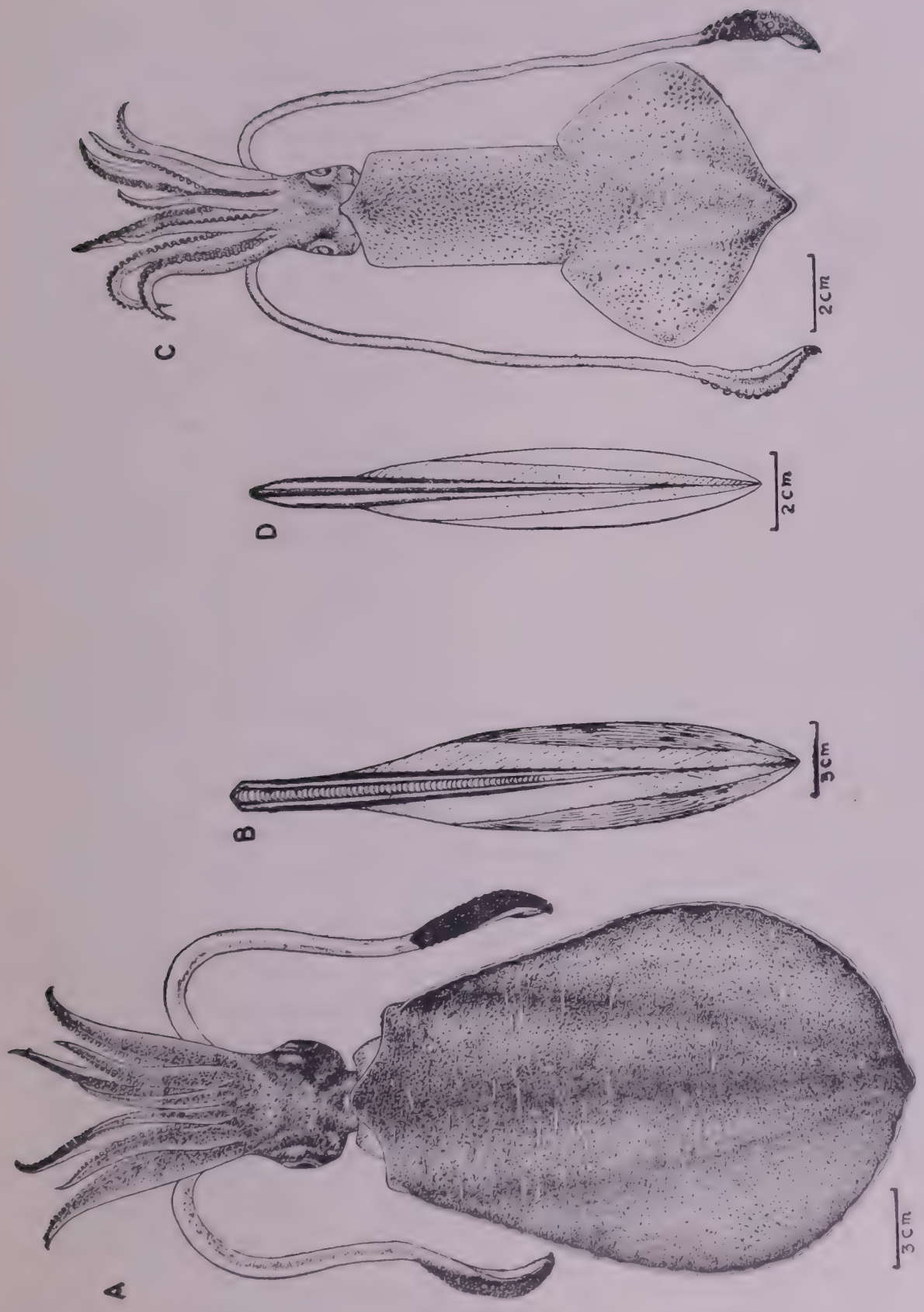

Fig. 5

Food

S. arctipinnis chiefly feeds on smaller fishes and sometimes on crustaceans consisting of crabs and prawns. They also consume smaller individuals of their own species. The cannibalistic habit is reported to be quite common among other species also (Allan, 1950; Fields, 1965). Generally squids are predaceous carnivores known to go in pursuit of their prey and tackle them with good amount of skill. Presumably, *S. arctipinnis* actively chases its prey consisting mostly of the fingerlings of fishes like *Sardinella* spp., *Syngnathoides bimaculatus, Atherina forskalii, Pelates quadrilineatus, Upeneus vittatus, Therapon puta, Gerres poeti, Leiognathus* spp. etc., and attack them with their powerful beaks.

Growth

They grow to a size of 95 mm, 166 mm and 219.5 mm in dorsal mantle length by the end of first, second and third years of their lives. At first they grow at a faster rate; the growth rate in the first year is 95 mm, in the second year 71 mm and in the third year 53 mm. Generally males tend to grow to a larger size than the females. Males attain a maximum size of about 259 mm weighing about 600 grams and the females 181 mm weighing about 300 grams. As the individuals grow older the sexual dimorphic characters become well-marked. The males attain maturity at the age of 6 to 14 months within a size range of 67.5 mm to 112.5 mm and females at the age of 12 to 14 months within a size range of 102.5 mm to 112.5 mm in dorsal mantle length. Mature male squids, prior to spawning are normally in very good condition. The testes are glossy in appearance and the Needham's sac is full of spermatophores. The females contain ovaries with numerous ripe eggs, the nidamental glands are glossy and large in size, and the accessory nidamental glands orange in colour.

Spawning

Spawning in these squids appears to commence from January in the off-shore waters when spawning population starts its migration into inshore shallow waters and coastal lagoons where they continue to spawn till the end of June. The members of the principal spawning group do not seem to feed. They deposit their eggs on objects like sea weeds, twigs, branches etc. After spawning squids show tremendous changes in their condition. The spent females lose their weight considerably their mantles become flaccid, the nidamental and accessory nidamental glands become thin and less glossy. Males also show changes but not as profound as in the case of females; their mantles and fins alone become somewhat limp. Such post-spawning changes are presented by other species also (McGowan, 1954; Fields 1965). In the case of *S. arctipinnis* the life span of the individuals is reported to be two years for females and three years for males.

The egg capsules of *S. arctipinnis* are most commonly met with in Palk Bay and Gulf of Mannar during the spawning period. Each egg capsule contains

about 6 to 7 eggs arranged in a single row (Alagarswami, 1966). It takes about a little more than 15 days for the eggs to develop into young ones and hatch out under normal conditions at a temperature range of 22 to 29 C. The just hatched young are about 7.5 mm in total length and 3.0 mm in width. The mantle of the tiny young is transparent and the well-developed visceral organs are clearly seen through the mantle. Chromatophores are present all over the body except on the ventral side of the fins. Remarkably, the just hatched young do not possess the characteristic broad fins but they are present in the posterior extremity of the mantle as a pair of small flaps. Normally they do not survive for prolonged period in aquarium.

Loligo duvauceli d' Orbigny

(= *L. indica* Pfeffer)

Common name

Tamil – *Oosi kanavai, Oosi kadama, Nedurg kadama.*

This is a common Indo-Malayan species occurring from South Africa to Formosa (Voss, 1963). In India it is commonly found on the east and west coasts

L. duvauceli is a smaller species readily distinguishable from *Sepioteuthis arctipinnis* from the following characters : the mantle is slender and tubular in outline and tapers gradually from about the middle to a blunt posterior end; the fins are smaller and rhomboidal in shape (Fig. 5 C). Unlike *S. arctipinnis*, the fins in this species are restricted to the posterior end of the mantle. The narrow head possesses ten arms including the two long slender tentacles. Sessile arms usually in the order 3.4.2.1. in length; suckers arranged in two rows in all arms; chitinous rings of the arm suckers possess about 6 to 8 teeth and sometimes more as in the case of larger suckers of males; tentacular clubs bear four rows of suckers, the rings of which are equipped with 17 to 20 teeth; distal half of the left arm of the male is hectocotylized; the gladius is narrow and slightly brownish in colour (Fig. 5 D); the ink sac possesses two small light organs one on either side.

No published information is available on the biology of this squid. They are usually caught in shore seines, boat seines and largely in trawl nets almost all through the year from Cape Comorin to Calcutta on the east coast and all along the west coast. Although they are caught all round the year in varying amounts their abundance appears to be from May to September in the Palk Bay. The peak of the season appears to be from June to August when large heaps of them are regularly seen in the markets along with other squids and cuttlefish. The size ranges from 50 mm to 120 mm and occasionally around 160 mm in dorsal mantle length. The females tend to grow larger than the males.

Apart from the afore-mentioned species others are considered unimportant as they occur only in stray numbers or because they are not utilized as food. *Euprymna stenodactyla* is usually caught in shore seines in good numbers in early hours of the day. They are commonly preyed upon by fishes like carangids. *Loliolus investigatoris* is a smaller squid which is occasionally caught in good quantities in seines and trawl nets but they are used neither for food nor bait owing to their small size. *Symplectoteuthis oualaniensis* is a larger ommastrephid squid an oceanic species which is occasionally captured in drift nets from Palk Bay and Gulf of Mannar.

CUTTLEFISH

Cuttlefishes belong to the order Sepioidea. Like squids, they possess well-defined head and ten arms. They have a broad and flattened body with narrow fins running along the sides to the full length of the body. The arms are comparatively short and provided with subequal suckers mostly arranged in four transverse rows. The two long, slender tentacles are retractile into special pockets and used at the time of capturing the prey. The characteristic internal shell or the cuttlebone is calcified and differs in shape and size in different species.

They are only three of species of cuttlefish viz., *Sepia pharaonis*, *Sepia aculeata* and *Sepiella inermis* which occur widely in India.

Sepia pharaonis Ehrenberg

(=*S. rouxii* Fèrussac and d'Orbigny)

This is the largest of species of cuttlefish found in our waters. Widely distributed in the Indo-Pacific it occurs all along the Indian coasts.

Description

The body of the cuttlefish is stout and oval in outline and widest at the anterior end. In front, the mantle is produced middorsally into a triangular lobe and midventrally slightly emarginated; fins very wide and fleshy and originate a few millimetres behind the anterior margin of the mantle; fins broad, extend along the periphery of the mantle and reach the posterior extremity; funnel large and thick walled, reaching almost to the base of the ventral arms; a triangular valve present in the funnel (Fig. 6 A).

The head is a little narrower than the mantle opening; mouth surrounded by seven buccal lappets, the edges of which are beset with minute suckers; arms subequal in length and attenuated; suckers arranged in four transverse rows on the arms and bordered by protective membranes; horny rings of the arm suckers have numerous palisaded teeth; tentacles long, thick and triangular in cross section; tentacular clubs are broad and fringed with strong swimming

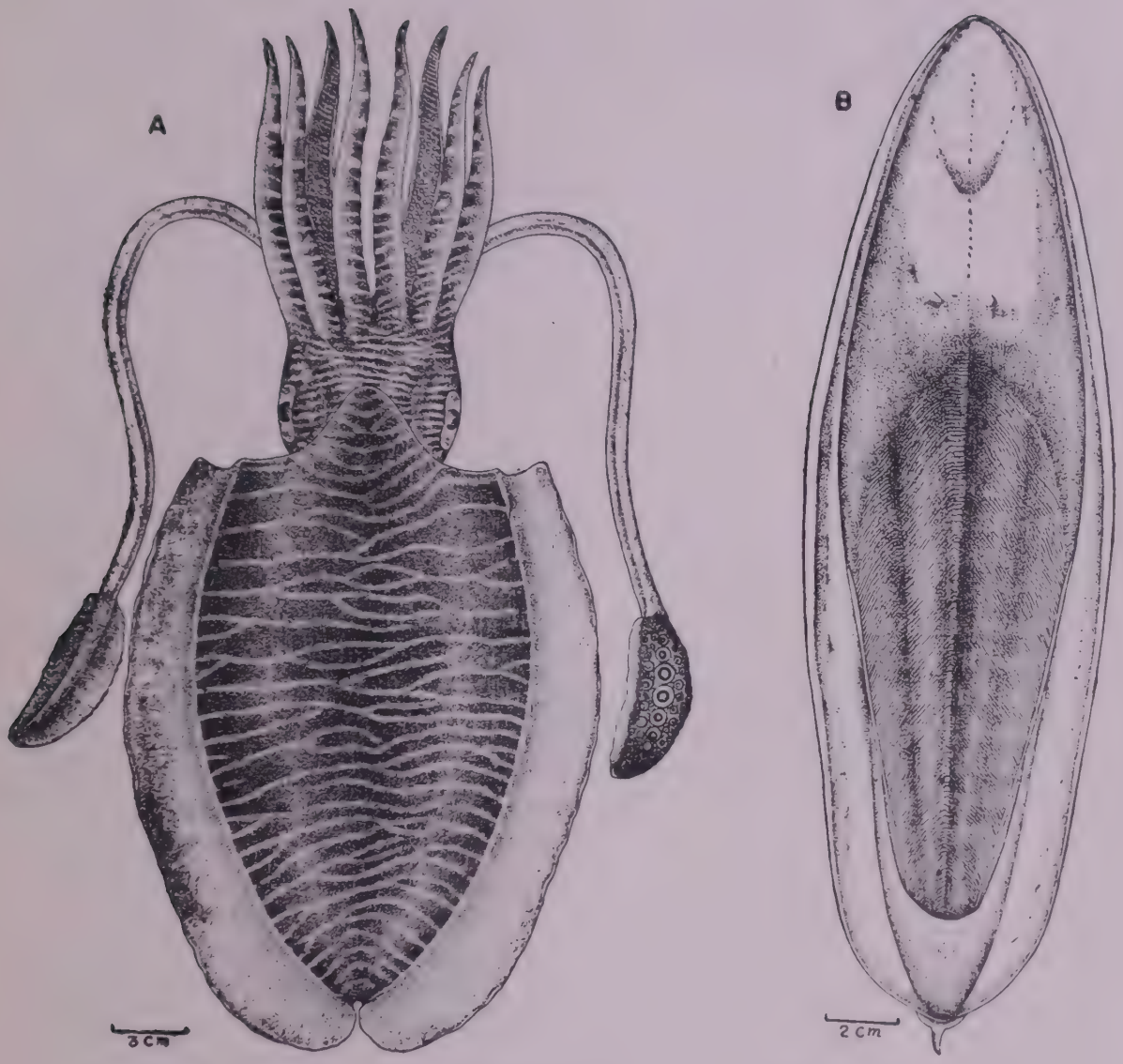

Fig. 6. A. *Sepia pharaonis* Ehrenberg Dorsal view. B. Cuttlebone of *S. pharaonis*.

membrane on the right side; there are about 113 unequal suckers arranged in five to seven oblique rows; of the suckers, two rows in the middle are greatly enlarged in about seven series, the seventh and the eighth from the base are exceedingly large; horny rings of club suckers smooth.

Cuttlebone is elongate and broadest at about the middle ; there are three low longitudinal ribs and broad chitinous margins on the dorsal surface ; ventral surface is concave posteriorly and convex anteriorly ; there is a shallow but distinct median groove running along the entire length of the striated area ; the striae are distinctly ∧ shaped ; the inner cone of the bone forms a characteristic plate-like callosity at the posterior end ; a small but thick spine is present at the posterior extremity (Fig. 6 B).

The dorsal surface of the mantle integument, head and arms is ornamented with conspicuous transverse stripes. The species is readily distinguished from all other cuttlefish by the presence of these stripes on the body, enlarged suckers of the clubs, broad plate-like inner cone, ∧ shaped striae and the distinct medium furrow on the ventral side of the cuttlebone.

Fishery

These cuttlefish are usually captured in small numbers in many places like Visakhapatnam, Cuddalore, Nagapattinam, Kilakarai and Rameswaram. Good quantities are caught with hand-line and scoop nets at Cape Comorin, Colachel and Vizhinjam. The cuttlebone of this species is commercially important and large quantities are collected from the beaches during November and December at Rameswaram and during March and April at Thiruppalakudi and Tondi in Ramanathapuram district. Considerable quantities are also collected from Kerala coast. Despite its availability in good abundance *S. pharaonis* seems to be commercially a less utilized species. Spawning grounds of *S. pharaonis* have been located off Orissa and Visakhapatnam (F.A.O./UN, 1961).

Sepia aculeata Fèrussac and d'Orbigny

Unlike the former species this is caught in much larger quantities especially along with *Loligo duvauceli* from Palk Bay and the Gulf of Mannar in trawl nets. Geographically this is distributed in the Indo-Pacific and in India reported from both the coasts.

Description

The mantle is roughly oval, broadest near the anterior end ; ventral margin of the mantle concave in the middle, middorsal projection has well-excavated sides ; fins narrow and originate a little behind the anterior margin of the mantle on the sides and extend to the end of the body where they are almost in contact with each other ; head narrower than mantle opening ; funnel short and does

not reach the base of the ventral arms ; buccal lappets surrounding mouth are seven, with minute suckers at their extreme ends (Fig. 7 A).

Arms short and subequal in length ; dorsal arms slightly rounded ventral arms provided with strong swimming membranes. Suction cups uniformly quadriserial on all arms and have dentate horny rings; ventral arm of the male is hectocotylized at the base ; tentacles slender and relatively thinner than the sessile arms ; tentacular clubs elongate but not much expanded ; swimming membrane of the club very narrow ; suckers are numerous and minute in size ; the cuttlebone possesses a longitudinal mid-ventral ridge in the striated area and the striae are notched in the middle ; the posterior inner cone is not plate-like but raised into a thick rounded ridge ; there is a small spine at the posterior extremity which is slightly pointed upwards (Fig. 7 B).

The commercial catches are represented by individuals ranging in size between 50 mm and 150 mm in dorsal mantle length and 17 and 500 grams in weight. A preliminary analysis of the gut contents of the cuttlefish shows that chiefly fishes and crustaceans and occasionally polychaetes comprise the main items of diet. *S. aculeata* appears to breed biannually (Rahaman, 1967). The first period of breeding season extends from February to April and the second period between July and August.

Sepiella inermis (Fèrussac and d'Orbigny)

This species can be readily recognized by its smaller size, presence of a distinct minute pore at the posterior end of the mantle, and the absence of a spine in the cuttlebone. The cuttlebone is altogether different in shape (Figs. 7 C, D and E). Widely distributed in the Indian Ocean, from Red sea to Indonesia and Cochin-China it is reported from both the coasts of India (Adam and Rees, 1966). The species range in size between 40 mm and 55 mm in the commercial landings. Though they are quite commonly caught in trawl nets in good numbers they do not seem to have any commercial value. When caught in large quantities they are either used for bait or discarded from the catch but not used for food. Nevertheless, in some places like Madras and Pondicherry they are favoured as food but only by certain fishermen and poor classes of people, and are sold either at the landing centres or markets in fresh condition.

OCTOPI

Octopi belonging to the Order Octopoda, possess a short rounded body and a distinct head fringed with eight arms, which are provided with a broad interbrachial membrane. The saccular mantle lacks fins. The suckers, arranged in two rows, are without stalks and horny rings. The animals are solitary in habit and mostly live in shallows crawling on the bottom, often hiding themselves in the crevices among rocks. Crabs and bivalves form their favourite food and

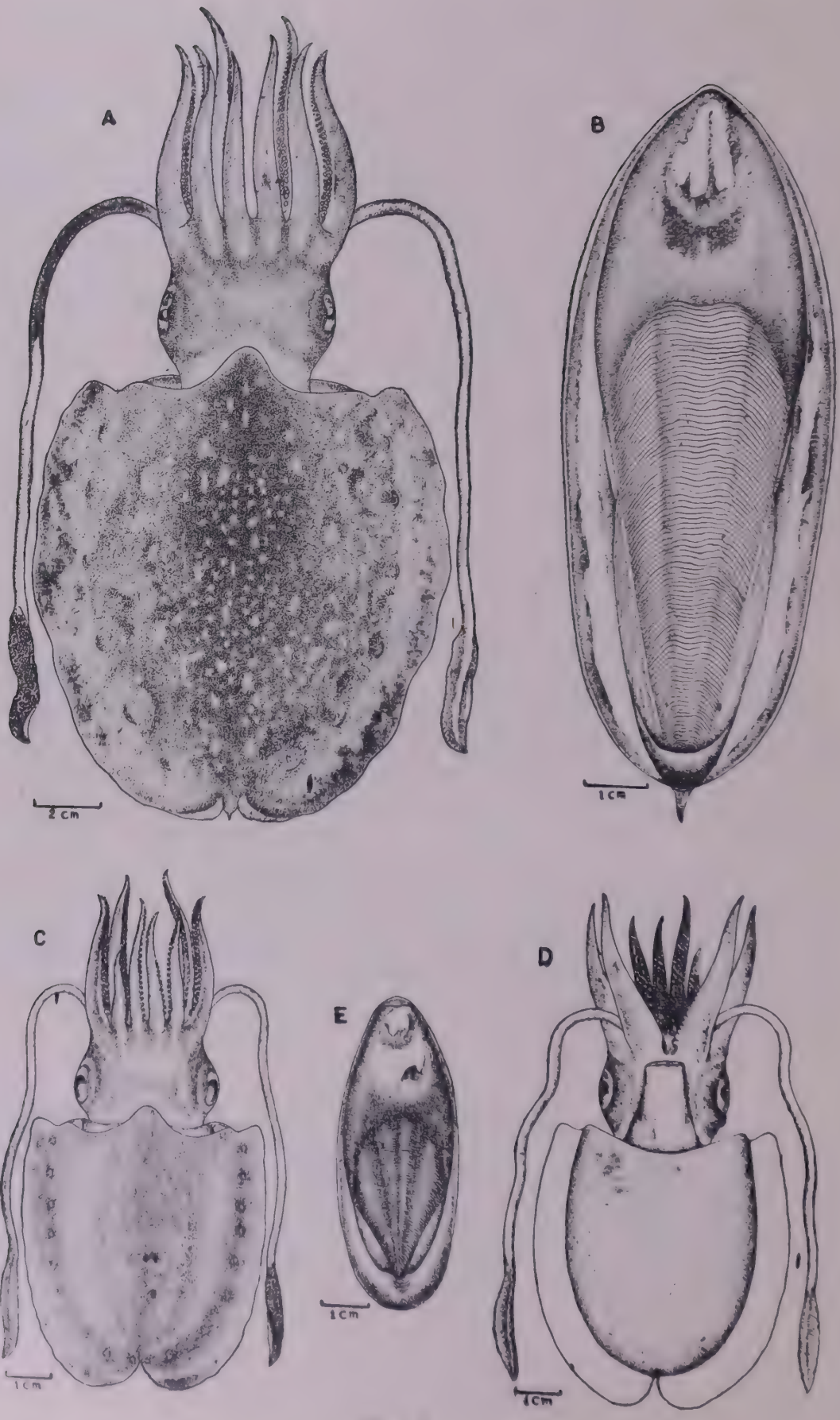

Fig. 7

smaller shrimps and fishes are also preyed upon by them. Several octopi are known to occur in Indian seas. *Octopus herdmani* Hoyle, *O. globosus* Appelöff, and *O. dollfusi* are the common shallow water forms of the Palk Pay and the Gulf of Mannar. No information is available on the biology of these octopi. They are called *pey kanavai* in Tamil. Octopi are well-known sea food in Japan and the people of countries like Spain, Italy and Philippines also relish octopi (Araya, 1967). Octopus is not much liked as food in India, excepting by those who are accustomed to eating it. In the Laccadives octopi are sought for being used as food and regular 'octopus hunting' is pursued. Their use as bait is widespread in the south-eastern coast of India. A number of octopi are caught in specially devised shell traps exclusively for bait in hook and line fishery especially along the Palk Bay (Hornell, 1917). A smaller species of Octopus locally called *sangu kanavai* is largely caught in this bait fishery. Octopi usually thrive well in capitivity. Preliminary observations on *O. dollfusi* show that they lay their eggs in festoons. They brood over the developing eggs with good amount of care till they hatch. Generally it takes about two weeks for the eggs to hatch out. The just hatched young range in size between 3.3 and 3.8 mm in mantle length.

The common species of octopus which usually abound on the pearl banks is *Octopus herdmani* Hoyle. Considerable damage is inflicted by these octopi upon pearl oysters by preying upon them. Many instances of *O. herdmani* predating on young oysters have been reported (FAO/UN, 1960). Another small, slender octopus locally known as *visha kanavai* (poisonous octopus) is said to be dangerous owing to its poisonous bite and they are never used as bait or food. When encountered in nets it is usually discarded immediately. Otherwise it tries to fasten on the limbs and bite through the skin. The pain received from the bite is likened to the sting of a scorpion and if not treated immediately the limb will swell and a feeling of giddiness will be experienced and sometimes the effect lasts for several months.

METHODS OF FISHING

The squids, cuttlefish and octopi are captured by various means. In general they are caught incidentally along with other food fishes in shore seines, trawl nets, boat seines and cast nets. In special methods a knowledge of the behaviour of the particular form is also made use of for capture. The shoaling behaviour and the shoreward migration during the spawning of squids and cuttlefish are exploited in fishing.

In the inshore waters of Palk Bay a special type of shore seines called *ola valai* is used for the capture of squids exclusively *Sepioteuthis arctipinnis* from

Fig. 7 A. *Sepia aculeata* Fèrussac and d'Orbigny Dorsal view. B. Cuttlebone of *S. aculeata*. C. *Sepiella inermis* (Fèrussac and d' Orbigny) Dorsal view. D. *S. inermis* Ventral view. E. Cuttlebone of *S. inermis*.

April to June and to minor extent from October to November. The *ola valai* (*olai*, palm leaf; *valai*, net) is utilized for squid fishing during the peak of the season i.e., May to June in Rameswaram Island, Mandapam, Devipatnam and Tondi along Palk Bay and in certain places like Rameswaram, Pamban, Mandapam, Pudumadam, Periapatnam, Kilakarai and Muthupettai along the Gulf of Mannar. The details of squid fishing by this method has been described by Rao (1954). The *ola valai* consists of a close-meshed rectangular bag about 8 m × 2 m and wing ropes of about 270 m in length. The latter bear strips of palm-leaf along the length in three or four close-set rows near the wings and in a double or single row in the rest of the length. The mode of operation is like that of any shore seine. Leaving one of the wing ropes ashore, the net is set from a rowing boat in a semicircular way, with the opening of the net facing the shore, thereby encircling a school of squids that may be present. The other end of the wing rope is brought back to the shore and subsequently the net is hauled. The palm-leaf strips of the wing ropes are intended to entice the squids into the bunt of the net.

Throughout April and May when shoals of squids appear off Rameswaram, Mandapam, Tondi and Devipatnam the *ola valai* are operated regularly and large quantities are landed. Squids are obtained in Gulf of Mannar in shore seine catches throughout the year in small numbers.

During the peak of the season special squid jiggers were used previously for capturing squids and the larger species of cuttlefishes in the Palk Bay region as described by Hornell (1917). In this method a special Y-shaped pole called *machan* with a bar across the bifurcated branching of the pole is erected in shallow coastal areas. The *machan* is used as a look-out post by the fisherman who sits on the cross bar with a long jigger consisting of 5 to 6 hooks arranged in grapnell fashion. The hook-end of the jigger is hidden under a heap of leaves arranged near the machan as a lure for the squids. When female squids and males in pursuit of them approach the leaves for depositing eggs, they are lifted off water with a jerk movement of the jigger.

This once extensively used method is not practised now. At the present time squid jigging is followed in a modified way. When shoals are seen, fishermen especially at Devipatnam, Thiruppalakudi and Rameswaram go in canoes or catamarans equipped with jigger. The jigger consists of a 35 to 40 cms long sturdy wire furnished at one end with three or four strong hooks. The other end is tightly tied to a slender pole which serves as the handle. When squids move within the reach of the jigger fishermen cautiously hook them individually with a quick jerk of the jigger and haul them into the boat. In this manner a large number of them are caught in a day. Occasionally large species of cuttlefishes like *Sepia pharaonis* are also captured by this method when they are encountered.

The squid *Loligo duvauceli* and the cuttlefish *Sepia aculeata* are usually captured in shore seines and boat seines only in small numbers. Until the introduction of trawl fishing on the south-east coast and other parts of the country it was generally considered that they were less abundant. Now, with the use of mechanised vessels and extension of fishing to the offshore areas much higher yields of *Sepia aculeata* and *Loligo duvauceli* are regularly obtained. The season for these species lasts from March to August. Although available extensively throughout India, they are fished to a greater extent from the Palk Bay and Gulf of Mannar close to Mandapam and Rameswaram.

Baited hooks and scoop nets are employed to catch *Sepia pharaonis* occasionally at Vizhinjam, Colachel and Cape Comorin. Fishermen reach the fishing ground in catamaran trolling a hand-line consisting of baited hooks which serve as snare. The cuttlefish thus attracted by the bait are dragged near the catamaran by slowly raising the line and taken with scoop net. In this way considerable number of them are procured.

The octopi are captured by employing various methods. The techniques range from hunting with spear to fishing with traps. In Minicoy island men, boys and girls collect octopus called *appalu* in local language from the coral reefs with two thick iron rods during favourable tide. As soon as the octopus is spotted among the crevices or holes in coral reefs one of the sharp ends of the rods is thrust into the quarry forcibly and hauled with the help of another rod. The octopus is then killed by the widely practised method called ' turning the cap ' i.e, by pushing the viscera out through the mantle opening.

Another method of catching octopus is also used in the bait fishery in the coastal villages bordering Palk Bay particularly at Tondi and Thiruppalakudi. The octopi, especially *O. globosus* are captured in shell traps. The shell traps are made of indigenous materials such as empty sea shells, thin coir ropes and wooden floats. Empty molluscan shells, largely *Lambis lambis*, *Tonna dolium*, *Rapana bulbosa, Murex virgineus* and *Hemifusus* are utilized for making such lines. The finger-like projections of *Lambis lambis* are usually broken off before being used, 100 to 120 of these shells are strung along a thin coir rope each 15 to 20 cm apart. A number of such lines are laid at the bottom of the sea at four to six metres depth and the ends of the lines buoyed with large wooden floats. Such traps are raised daily by the fishermen and the small octopi *O. dollfusi* and *O. globosus* which take refuge in the hollows of the shells are extracted with a strong needle and utilized as bait. The shell traps are again laid at the same place for further use. After prolonged time of using the lines are periodically brought ashore and dried. The bait fishery is suspended during the rainy seasons.

It is of interest to mention briefly the methods that are employed in the

cephalopod fishery in other parts of the world. One of the most widely practised methods for capturing squids and cuttlefishes is jigging. The Japanese squid jigging method is very efficient for squid fishing. Jigging is the method by which the world's largest catch of cephalopods is fished by Japan. The jigger consists of hooks fixed with a lead weight at one end in a circular fashion or with a bait fish. The hooks are sometimes intensely coloured to attract squids. The jigger is lowered into the water either with or without bait and the squids which rush towards the jigger are captured with a hand net or the jigger is hauled quickly into the boat. Multiple mechanical jiggers are used at present in Japan (Araya, 1967).

The commercial squid fishing in California is carried out with lampara nets, Fishing is done during night by encircling the school of squids, attracted by lights, from the boat, and hauling into the boat by power lifted dip nets (Fields, 1950). With a view to avoid brailing and to reduce the crew required in this method of fishing, squid slurp has been recently experimented in California squid fishery in San Pedro (Anonymous, 1970).

PREPARATION OF THE CATCH FOR THE MARKET

Mostly squids and cuttlefish are sold in the markets in fresh condition and only limited quantities in dried condition. After capture the larger species of squids and cuttlefish are split open on the midventral plane to remove the ink sacs as otherwise the whole lot will become undesirably stained with the dark ink. Generally the ink sac of smaller species like *Loligo duvauceli* is not removed before being sent to the markets. At Mandapam where large quantities of *L. duvauceli* are caught in trawl nets the entire catch is loaded in baskets with crushed ice and sent to Ramnad and Kilakarai markets where they are sold in lots. Usually *Sepioteuthis* fetches a higher price than other cephalopods. The price varies aocording to the size from 25 ps. for smaller individuals to 75 ps. for larger ones. *Loligo duvauceli* and *Sepia aculeata* are sold in lots each consisting on an average of 4 to 6 numbers. Each lot varies in price from 25 ps. to 35 ps. at Ramnad market and fetches rather higher price at Kilakarai market where the local population very much relish them.

When the catches are enormous, as during the peak of the seasons, a small portion of them is cured. For this purpose *Sepioteuthis arctipinnis* and *Sepia pharaonis* are split open and the ink sac, viscera and the shell are removed on the field. To remove the shell a small slit is made at the anterior end of the dorsal side of the mantle and the shell is pulled out. The pigmented integument of the mantle is peeled off and the mantle is washed in sea water. Then the mantle appears whitish and attractive. Sometimes the head and the arms are also discarded and the mantle portion alone utilized. The mantles are sun-dried either with or without salt. On drying the product usually becomes a little hard.

In the case of smaller cephalopods like *Loligo duvauceli*, *Sepia aculeata* and *Sepiella inermis*, they are simply dried without washing and removal of shell and visceral components. Such crude product is inferior in quality and sold at relatively cheaper rate.

An improved method has recently been attempted in the Indo-Norwegian Project to process cuttlefish and squids. The new product developed is called ' fingers ' of squids and cuttlefish. Iced squids and cuttlefish (*Loligo sp.* and *Sepia aculeata*) are used to manufacture these. The raw materials are well washed in bacteriologically pure and chlorinated water and the cuttlebone and outer chromatophoric layer of mantle are removed. The mantles of the squids and cuttelfishes are then cut into uniform strips each measuring about 2 to 2·5 cm. in thickness and suitable size. The resulting ' fingers ' are packed in cartons which are lined with a sheet of polythene. The cartons thus packed are quick frozen at a temperature of − 35 ° C to − 40 ° C. This frozen product remains in good condition up to six months with flavour that is comparable with fresh product. The product is especially fine with spices (Padmanabhan, 1970).

UTILIZATION AND ECONOMIC IMPORTANCE OF CEPHALOPODS

Most of the squids cuttlefish and octopi are valued as food and bait in many parts of the world. Especially people of Japan, Korea, Mediterranean countries, Philippines, Malaysia, Indonesia and Taiwan extensively utilize cephalopods as food. In India only squids are relished to a large extent among the cephalopods. The meat of cephalopods is clean, attractive and has good flavour. It is also highly nutritive. The basic organic constituents of the squid meat and utility of the meat as human food from the point of view of digestibility and nutrition have been extensively studied by Japanese workers (Takahashi, 1960; Tanikawa and Suno, 1952). As a result it is considered that the squid meat may be a perfect source of protein (Takahashi, 1965). Generally the percentage yield of the edible portion of squid at 80 % of which the mantle forms 50 % and arms 30 %. The protein content of the squid is nearly 20 % wet weight which is in favourable comparison with commercially important fishes. The calorific value of the Japanese squid when seasoned is estimated at 117 cal / 100 g and the main constituents are crude protein 17·3 %, fat 1·83 % and carbohydrates 7·11 % wet wt (Tanikawa and Suno, 1952; Dracowich and Kelly, 1963).

The meat of cephalopods is prepared in many ways for food. Fresh meat is cut into slices and treated with spices and fried, or cooked into curries, cutlets or soup. In most of the preparations the white meat is sliced to frying size and well pounded before being cooked to render the flesh soft. In the Philippines the meat of squids and octopus is first boiled in vinegar with crushed garlic and then fried with oil and spices (Voss, 1963).

Cephalopods are used as bait. Cephalopods are utilized as biological material in neuro-physiological researches pertaining to the conduction of nerve impulses (Walford, 1958). Squids are used as manure (Clarke, 1963). The cuttlebones of cuttlefish are commercially valuable because of their calcium content. They are used in the preparation of abrasives and dentrifices (Dees, 1961). They are used in poultry and bird cages as a source of calcium and as grinding stone for beaks. Certain medicinal properties are also attributed to the bones and ink of cuttlefish (*vide* Boycott, 1957). The ink has been used by artists as a natural 'sepia' pigment in olden times. The pulvurized cuttlebones are used for rendering smooth the surface of wood-work and motor vehicles before they are painted. They are also used in jewellery making for moulding purposes.

Certain by-products such as oil and liver extract are also produced from squids, especially in Japan. The squid liver extract is used as human food and the same in condensed or dehydrated form serves as feed for live–stock (Takahashi, 1965). The viscera of squids is supposed to be ideal material as domestic poultry feed (Kawata *et. al.*, 1955). Cephalopods form an indirect source of another commercially much valued commodity, ambergris, which is widely used as a fixative in perfumery (Idyll, 1958). Ambergris is supposed to be formed directly from the sperm whales faeces adhering round horny beaks of squids (Lane, 1962).

At present in India squids and cuttlefish are largely fished to meet the domestic demand that exists mainly in coastal villages. Our annual production is meagre when compared with other well developed fisheries elsewhere. As shown in Table VII the annual landings of India for the period from 1959 to 1969 fluctuate between 94 tonnes in 1961 and 1515 tonnes in 1968. The average annual

TABLE VII

Cephalopod landings and their percentage in total marine landings in India from 1959 to 1968. Figures in tonnes. (C.M.F.R.I., 1969 a; 1969 b)

Year	Cephalopod landings	Total marine landings	Percentage of Cephalopods
1959	349	584587	0.05
1960	467	879681	0.05
1961	94	683569	0.01
1962	97	644244	0.01
1963	260	655484	0.03
1964	464	859582	0.05
1965	265	832777	0.03
1966	952	890311	1.00
1967	521	863879	0.06
1968	1515	902772	1.60
1969	769	913630	0.80

landings are estimated at 498 tonnes for the period. Cephalopod landings of different states are given in Table VIII. It is evident from the Table that Kerala and Maharashtra on the west coast and Tamil Nadu and Andhra on the east coast are the principal states that contribute higher percentages of landings. Though there seems to be no regular organised fishery for cephalopods on the west coast

TABLE VIII

State-wise and year-wise cephalopod landings during the period 1959 to 1968 in India. Figures in tonnes. (after C.M.F.R.I., 1969 a)

State	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
West Bengal & Orissa			6	12	1	5		1		19
Andhra	3	1		5	10	22		13	4	71
Madras		18	5	2	29	74	84	195	140	188
Kerala	288	417	28	17	180	340	174	714	374	1122
Mysore	15	14	1	7	13	1	1	1		13
Maharashtra	42	12	53	53	27	22	7	26	2	101
Gujarat				1		1	1	1	1	1
Goa	1	5	1					1		

the incidental catches amount to 82% of the total cephalopod catches (Table IX). There is good scope for India to increase cephalopod catches by exploiting the resources in the continental shelf and beyond it. Some of the potentially

TABLE IX

Cephaloped landings of the West and East coasts of India during 1959 to 1968. Figures in tonnes, (after C.M.F.R.I., 1969 a).

Year	West coast	East coast	Total
1959	346	3	349
1960	448	19	467
1961	83	11	94
1962	78	19	97
1963	220	40	260
1964	363	101	464
1965	183	82	265
1966	743	209	952
1967	377	144	521
1968	1237	278	1515

important species which occur in fair abundance in the Indian Ocean are *Symplectoteuthis oulaniensis, S. luminosa, Ommastrephes bartrami, Todarodes sagittatus* and *Notodarus sloanii*. Of these *S. oulaniensis* is the most abundant and predominantly distributed in the northern and central parts of the Indian Ocean and *O. bartrami* and *T. sagittatus* are distributed in the southern parts (Filippova, 1968).

There exists an export market for Indian cuttlebones. Cuttlebones are regularly reported to U.K., U.S.A. and Burma. For this purpose cuttlebones of *Sepia pharaonis* are preferred to others because of their larger size. The cuttlebones are exported through agents in Tuticorin. Before shipment the bones are well washed with soap water and perfectly dried. The chitinous edges of the bones are trimmed and quantities of such products are exported. Between 1963 and 1968 a total of 63,184 kg of cuttlebones valued at Rs. 2,41,431 have been exported from India (Table X).

TABLE X

Quantity and commercial value of cuttlebones exported from India between 1963 and 1968 (after C.M.F.R.I., 1969 a).

Year	Quantity of cuttlebones (Kg)	Value in Rupees
1963	421	11,139
1964	7,715	18,890
1965	7,968	37,184
1966	17,345	50,384
1967	2,507	25,783
1968	27,228	98,051
Total :	63,184	2,43,431
Average :	10,530	40,571

The present status of the world cephalopod fisheries is shown in Table XI. Annually about 0·9 million tonnes of squids, cuttlefish and octopi are landed. While cephalopods are caught almost in all maritime countries large scale fisheries are centered in North Pacific, especially in the seas around Japan and California, in the Mediterranean and in the North Atlantic. Japan has consistently been the world's largest producer of cephalopods contributing more than 75% annually to the world total cephaloped landings. Other important countries where large cephaloped fisheries exist are Korea, Spain, Italy, Philippines, China

TABLE XI

Cephalopod landings of different countries for the period 1963 to 1969 (landings in thousand tonnes) (after F.A.O., 1970a).

Country	1963	1964	1965	1966	1967	1968	1969
Japan	396·4	577·5	550·8	695·8	695·0	876 0	683·4
Korea	118·5	87·8	71·6	78·2	43·6	92·7	67·6
Spain	43·5	53·0	91·6	91·8	98·5	34·2	81·7
Italy	20·6	27·5	30·4	32·1	30·7	30·8	27·9
Philippines	6·8	7·6	10·0	11·4	9·9	17·9	13·1
China (Taiwan)	15·7	13·5	14·2	18·7	13·8	14·0	15·5
United States (Pacific)	5·2	7·5	8·4	8·7	9·0	11·5	9·4
United States(Atlantic)	2·2	1·0	1·2	1·2	1·8	1·7	1·7
Hongkong	1·9	1·5	1·4	2·4	1·7	2·5	3·8
Norway	0·5	1·5	10·8	2·5	1·9	0·1	–
England & Wales	0·1	0·1	0·1	0·1	0·1	0·1	0·2
Scotland	0·2	0·1	0·1	0·0	0·1	0·1	0·1
Canada (Atlantic)	2·4	10·8	7·9	5·1	7·0	0·0	0·0
Portugal	5·4	4·2	6·3	4·6	5·8	-	3·6
France	3·3	1·8	3·9	3·7	3·9	-	-

(Taiwan), U.S.A. and Canada. Japan exports huge quantities of cephalopods annually. She exported 7·1 thousand tonnes in 1969 to several countries like Malaysia, Philippines, Greece, Italy and Portugal (F.A.O., 1969b). Hongkong exports hundreds of tonnes of dried squids and cuttlefish to south-east Asian countries.

VI PEARL OYSTERS

K. Virabhadra Rao and K. Satyanarayana Rao

Pearls are formed in a number of species of molluscs *viz.*, the pearl oysters, window-pane oysters, edible oysters, fresh-water mussels, abalones, chanks, topshells, turban shells etc. Pearls formed in some of the pearl oyster species are valued very highly as gems because of their excellent shape, quality and lustre. Pearl oysters enjoy a world-wide distribution occuring in almost all the seas of the tropical belt. Six species of pearl oysters are known from the Indian coasts viz. *Pinctada fucata* (Gould), *P. margaritifera* (Linnaeus), *P. chemnitzii* (Philippi), *P. sugillata* (Reeve), *P. anomioides* (Reeve) and *P. atropurpurea* (Dunker). Of those, *P. fucata* which occurs in extensive beds in the Gulf of Mannar and to a much less extent in the Gulf of Kutch is commercially very important being the source of the 'Oriental pearls' or 'Lingah' pearls of great renown. *P. fucata* occurring in the Persian Gulf and off the coasts of Ceylon also supports excellent fisheries for natural pearls. The Indian pearl fisheries have been famous since ancient times for the most beautiful pearls they yield. The other five species of pearl oysters on the Indian coasts are not of any importance as their pearl yield is low or the pearls produced by them are not of high quality.

Genus PINCTADA Roding

Pearl oysters originally ascribed to the sub-genus *Margaritifera* under the genus *Pteria* are new referable to the genus *Pinctada* as pointed out by Prashad (1932), Iredale (1939) and Hynd (1955). Members of this genus are characterized by the following features : The hinge is long and straight; the long axis of the shell is at right angles to the hinge; the left valve is a little deeper than the right; there is a byssal notch on each valve at the base of the anterior lobe; the colouration of periostracum varies and is often brownish with radial markings (Rao, 1970).

Pinctada Fucata (Gould)

Synonyms

Perlamater vulgaris Schumacher 1817
Avicula fucata Gould 1850
Avicula periviridis; A. occa; A. lucunata; A. aerata; A. fucata Reeve 1857
Pteria (Margaritifera) vulgaris Jameson 1901

Margaritifera vulgaris Hornell 1922 a
Pinctada vulgaris Prashad 1932; Prasad and Bhaduri 1933; Satyamurthi 1965
Pteria vulgaris Gravely 1941
Pinctada fucata Hynd 1955 Rao 1970

COMMON NAME

Tamil – *Muthu chippi*
English – *Pearl oyster*

Jameson (1901) stated that *Perlamater vulgaris* of Schumacher (1817) was a recognizable species and that the specific name *fucata* of Gould (1850) should be replaced by the former. But Hynd (1955) considered that the description of Schumacher was too brief to be of value and that in the absence of type specimen and type locality the species should be held to be unidentifiable.

DESCRIPTION

SHELL

The hinge is fairly long, its ratio to the broadest region of the body of the shell is about 0.85 and its ratio to the longest dorso–ventral measurement is about 0.76. In both the valves there are hinge teeth, one each at the anterior and posterior ends of the ligament. The anterior ear is larger than in other species and the byssal notch at the junction of the body of the shell and the ear is slit like. The posterior ear is fairly well developed. The posterior border of the shell shows a small or moderately large sinus. The adductor impression is large and subcentral. There are 12 to 15 small scars caused by the insertion of pallial muscles between the umbo and the anteroventral border. The convexity of the valves is greater than in other species of the genus. The shells of the pearl oysters of Tuticorin pearl banks are reddishbrown or yellowish brown in colour with radiating rays of lighter colour. The non–nacreous border on the inner surface of the valves possesses brownish or reddish patches coinciding with the external rays. The nacreous layer is well developed in both the valves, golden yellow in colour and has a bright, metallic lustre (Fig. 8 A, B, C and D). The younger shells have thin, flat, marginal radiating blunt projections (Rao, 1970).

BODY

The soft body of the pearl oyster has been described by Herdman (1904) and Hornell (1922a) and it conforms to the general pattern of structure of the monomyarian lamellibranchs. It consists of a viscero–pedal mass covered by the right and left mantle lobes which are free anteriorly, ventrally and posteriorly but fused dorsally. The mantle edge has two thin, folds with pigmented, papillate edges. The outer fold is parallel to the inner surface of the shell and the inner fold called the pallial veil or velum projects at right angles from the

mantle edges. In life the pallial veils of the opposite sides are in contact with each other except in the regions of the inhalent aperture about mid-ventrally and the exhalent aperture at the posterior end. The foot is elongated and muscular arising about mid-way between the mouth and the intestinal lobe and has a groove ventrally. The byssus is at the proximal end of the foot and bears byssus fibres with which the pearl oyster attaches itself to the substratum.

The adductor muscle consists of a narrow region formed of white, glistening muscle fibres and a broad region of colourless semi-translucent fibres. The alimentary canal consists of the mouth provided with two pairs of labial palps, the oesophagus, the stomach and a coiled intestine. The digestive gland surrounds the stomach and in healthy oysters a crystalline style is present in the intestine. The rectum passes through the pericardium, curves ventrally and lies around the opsterior aspect of the adductor muscle terminating in the anus.

The gills are paired, sickle-shaped structures lying on either side of the viscero-pedal mass. The vascular system consists of a heart with paired auricles and a ventricle enclosed in a pericardium, and a series of arteries and venous sinuses in the visceral organs. The nervous system has the paired cerebral, pedal and visceral or parieto-splanchnic ganglia from which nerves run to different parts of the body. There are two nephridia one on either side of the posterior half of the viscero-pedal mass. The gonads are paired, asymmeterical and creamy yellow in colour. The gonadal follicles cover the stomach and part of the intestine (Fig. 8 E).

Distribution

Indian Ocean, Red Sea, Persian Gulf and Western Pacific Ocean.

Habitat

In the Gulf of Mannar the pearl oysters occur on rocky or dead coral outcrops forming the pearl banks known as 'paars' which off Tuticorin are about 8–12 miles (13 to 20 km) from the coast at a depth of 7 to 12 fathoms. There is usually a rich fauna comprising of members of various groups like sponges, hydroids, polychaetes, lamellibranchs, amphipods, crabs, echinoderms, fishes etc.

Fig. 8. *Pinctada fucata* (Gould). A. Left valve outer surface. B. Right valve outer surface. C. Left valve inner view. D. Right valve inner view (after Rao, 1970). E. Anotamy. (after Hornell, 1922). a.b.o., anterior border of shell valve; a.e., anterior ear; a.t., anterior hinge tooth; by.n., byssal notch; bys., byssus; dg.g., digestive gland; f., foot; g., gills; h. lig., hinge ligament; l., ligament; l.p., labial palps; m., mouth; m.sc., muscle scar; mt., mantle; n.b., nacreous border; n.n.b., non-nacreous border; p.bo., posterior border of shell valve; p.e., posterior ear; p.n.p., posterior nacreous border; p.si., posterior sinus; p.t., posterior hinge tooth; st., stomach; rct., rectum; um., umbo.

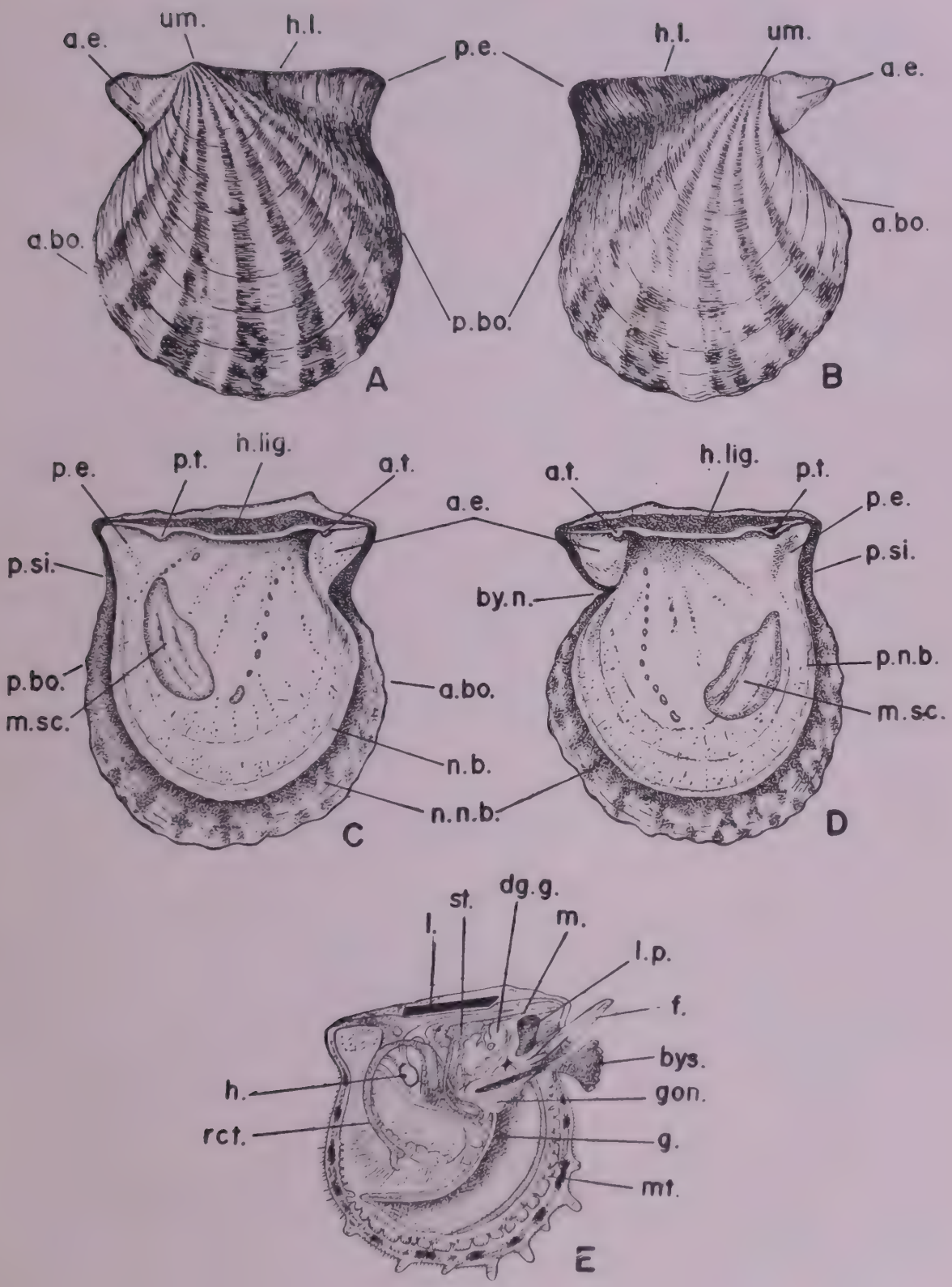
a.e.
um.
h.l.
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Fig. 8

associated with the pearl banks hamphering healthy growth and survival of pearl oysters. It is not uncommon to find fair abundance of marine algae also on the pearl banks. In the Gulf of Kutch the pearl oysters are found as stray individuals on the reefs some feet below the low water mark. *P. fucata* occurs sporadically on loose sandy or muddy substratum attached to the submerged objects in littoral waters in Palk Bay.

Habits

The pearl oyster attaches itself to the substratum firmly with the bundle of byssus threads, each thread having a discoid structure at the distal end for fixation. However, the shell-fish can move with the help of the foot over short distances after detaching the byssus threads from the substratum. The foot is also used by the oyster to free parts of its body like palps, gills and mantle from foreign materials like mud etc. which settle on them. The oyster generally lies on its right valve with the posterior edge elevated at an angie of 20 (Herdman, 1904).

Food and feeding habits

Like other free-living bivalves, the pearl oyster is a filter feeder. The feeding habits of *P. fucata* have been studied by Herdman (1903). Minute food organisms present in the water enter inside the pearl oyster long with water current passing through the narrow slit formed by the inwardly directed edges of the pallial lobes and they are carried towards the branchiae which act as fine strainers arresting every particle in the water current. The food particles collected thus are carried by the cilia to the crest of the branchial lamellae and from there they are directed by the labial palps into the mouth. The labial palps have the ability to reject unwanted materials like mud particles etc.

Reproduction

No information is available on the seasonal gonadal changes of *P. fucata*. Hornell (1922a) has mentioned that some ripe oysters can be seen at any period in the year. In Australian waters Tranter (1959) has recorded that gonad differentiation takes place in *P. fucata* between September and November, spawning between December and May and the gonads are in the resting phase between June and August. The peak spawning periods January–February and April–May were observed in Australian waters. Tranter has reported in *P. fucata* protandry and sex-change.

P. fucata of the Indian coast in the Gulf of Manner has two spawning seasons in the year in April - May and September - October (Hornell, 1916). Herdman (1906) has stated that in Ceylon waters *P. vulgaris* (= *P. fucata*) spawns between May and July and again in the period November - January. According to Malpas (1929) the species spawns in Ceylon in July - August and

December – January. Chacko (1970) has reported breeding of the species in all the months of the year.

Early Development

Herdman and Hornell as reported by Herdman (1903) have studied the early development of the pearl oyster. Fertilization is external. The egg when discharged is pyriform or flask-shaped but becomes spherical on fertilization. Segmentation is complete but unequal. The trochophore larva is formed about 20 hours after fertilization, having a pre-equatorial tuft and a patch of circlet of cilia at the opposite pole. The body becomes elongate and the equatorial band moves forwards and becomes a preoral circlet. By the end of the second day the veliger larva is formed with a shell and a velum. A little later the shell grows larger, the umbones are visible, rudiments of branchial filaments and otocysts appear and the anterior and the posterior adductor muscles are prominent. In older larvae the umbones of the shell are larger, the digestive gland is bilobed and there is an increase in the number of branchial filaments. Later the velum is reduced, the foot is prominent and is actively protruded and moved. The byssal gland is formed about the middle of the posterior edge and octocysts lie near the base of the foot. The larva then settles down as spat. In the earliest stage of spat which measures 0·1 mm in diameter the shell shows growth at the margin. At a size of 0·175 mm prismatic shell substance is deposited marginally. There is asymmetrical growth and the umbones are more anterior in position. A byssal sinus and a delicate byssus are devoloped for attachment. Further growth depends on the availability of suitable substratum and other favourable environmental conditions (Fig. 9 A-I).

Spatfall

Hornell (1905, 1916) considered that in the Gulf of Mannar the pearl oyster beds of the Indian coasts are periodically replenished by larvae which are transported by currents from the Ceylon coasts and in the like manner the beds on the Ceylon coasts are repopulated by larvae drifted from the Indian coasts. Hornell (1916) also opined that in addition to the above source the larvae coming from one coast populate adjacent beds along the same coast. Hornell's observations were supported by preliminary experiments with drift bottles which were released in the monsoon period and recovered along the coasts at certain points.

Growth

Observations made on pearl oysters in the pearl oyster farm near Krusadai Island by Devanesan and Chidambaram (1956) and at Tuticorin by Chacko (1954, 1956, 1957) show that the oysters grow to a height of about 36 mm in 6 months, 35-45 mm at the end of one year, 50-55 mm at the end of the second year, 55-60 mm at the end of the third year, 60-65 mm at the end of the fourth year and 65-70 mm

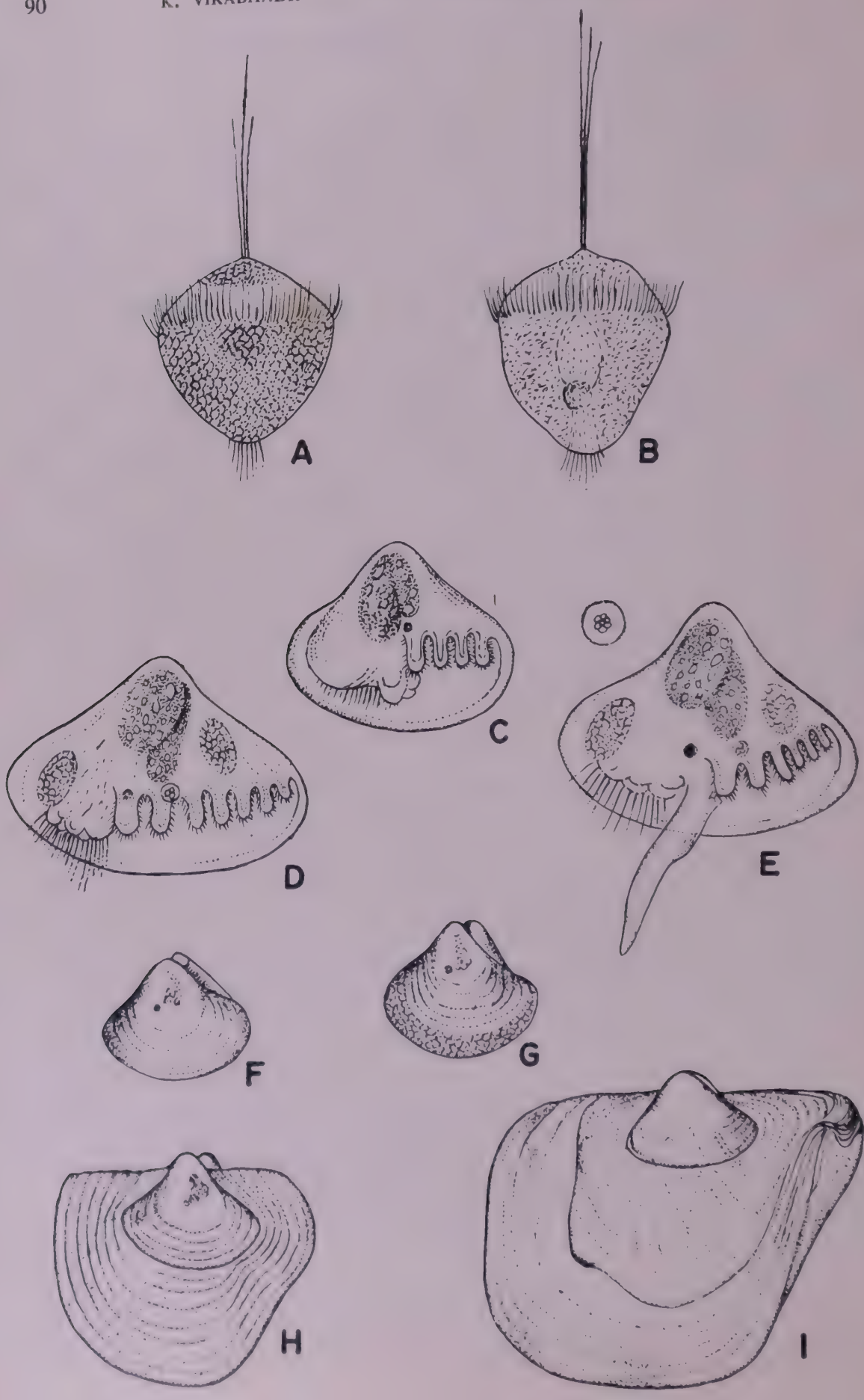

Fig. 9

at the end of the fifth year (Table XII). The pearl oysters have been estimated to have a longevity of 5–5½ years on natural beds but have been observed to live

TABLE XII

Growth of *Pinctada fucata* (after Chacko, 1970)

Age of Pearl Oysters (in month)	Length (Height) (mm)	Weight (gm)
< 6	< 36	< 5
6 – 12	35 – 45	5 – 10
12 – 18	45 – 50	10 – 20
18 – 24	50 – 55	20 – 30
24 – 36	55 – 60	30 – 45
36 – 48	60 – 65	45 – 60
48 – 60	65 – 70	60 – 70
60 – 72	70 – 75	70 – 80
> 72	> 75	> 80

upto seven years when reared in a farm. Gokhale *et. al.* (1954) and Narayanan and Michael (1968) have studied the growth and relation between age and linear measurements in the pearl oyster species occurring in the Gulf of Kutch, where its growth rate has been found to be slightly higher (Table XIII).

TABLE XIII

Weighed mean of length (height), breadth (width) and hinge length of *P. fucata* reared in a pearl oyster park in Gulf of Kutch (after Narayanan and Michael, 1968).

Age in Years	Length (Height) in mm	Breadth (Width) in mm	Hinge length in mm
1	44·05	42·14	38·42
2	61·68	58·93	55·45
3	76·20	67·66	62·00
4	81·62	74·32	66 09
5	85·15	77·35	69·37
6	86·65	80·50	72·44
7	86·67	76·70	69·84

Fig. 9. Early developmental stages of *Pinctada fucata*. A and B. Trochophore stages. C, D and E. Different phases of veliger stage. In E enlarged view of otocyst containing granules is shown separately. F, G, H and I. Pearl Oyster spat in progressive stages of growth (after Herdman and Hornell, 1903 and Hornell, 1916)

Narayanan and Michael (*loc. cit.*) observed that the growth rate of the pearl oysters as denoted by increase in length (height), breadth (width) and hinge length is not proportionate to age as growth is retarded after the sixth year. The increase in thickness and hinge width is more or less uniform during growth. It was stated that the thickness and hinge width of the pearl oysters are more dependable than height for determining age.

Parasites

The parasites of *Pinctada fucata* have been studied by Shipley and Hornell (1904) and Hornell (1922a). Roughly spherical cestode larvae are abundant in the tissues of the pearl oysters. Shipley and Hornell (*loc. cit.*) considered these to be the younger stage larvae of the species *Tetrarhynchus unionifactor* found encysted in the intestinal walls of the pearl oysters. Hornell (1922a) has stated that the early larvae recorded earlier may belong to the cestode genus *Tylocephalum* and not to this species. Dead cestode larvae commonly form the nucleus of cyst pearls of Indian and Ceylon pearl oysters Three species of trematodes *Mutta margaritiferae, Musalia herdmani, Aspidogaster margaritifeae* and three species of nematodes *Ascaris meleagrinae, Cheiracanthus uncinatus* and *Oxyuris* sp. have been recorded in *P. fucata* (Shipley and Hornell, *loc. cit.*). Detailed studies should be made of the parasitic species infesting *P. fucata* and their life-histories. The studies are of importance as it is (Hornell *loc. cit.*) believed that the cestode larvae are most important in the production of the larger and finer pearls.

Pests

Sponges, hydroids, polychaetes like *Eunice tubifex*, polynoids and serpulids, nemertines, polyzoans, mussels belonging to the genus *Modiolus* (*M. barbatus*), and crinoid *Antedon* sp., some ophiuroids and ascidians often occur on the surface of the pearl oysters, sometimes in large numbers and constitute serious pests. The presence of the epi-fauna weakens the shell and also prevents the healthy growth of the oysters. Sponges of *Cliona* spp. bore into the shells of the pearl oysters and causeheavy damage. Algae belonging to various genera such as *Padina*, *Gracilaria*, *Sargassum* and *Hypnaea* are also usually common on the pearl oyster beds and are not conducive for the healthy growth and survival of the oysters as they are engulfed by the algal masses.

Predators

Some invertebrate animals and fishes feed on the pearl oysters causing large mortalities. Among the invertebrates the starfish *Protoreaster lincki* (Blainville), the octopus *Polypus* sp. and *Murex ramosus* are the well-known predators. Of the fishes the important ones are *Balistes* sp., *Lethrinus* spp., *Serranus* spp., *Tetradon* and different species of sharks and rays. *Rhinoptera javanica* and *Ginglymostoma* are the main predators on adult pearl oysters. Rays

are responsible for large-scale mortality of them. The pearl oyster beds subjected to attacks by rays show large furrows made by these elasmobranchs and heaps of broken shells of oysters devoured by them (Hornell, 1916). Hornell (*loc. cit.*) considered that one of the primary factors resulting in alternating cycles of years with poor and rich pearl oyster populations over the banks is the abudance or scarcity of predators.

Pearl Fisheries

The pearl oyster resources in the Gulf of Mannar along the Indian coast have been harvested from time immemorial. In the Gulf of Mannar the pearl banks are located between Kanyakumari and Rameswaram at varying depths. They are grouped under three divisions viz. the northern or Kilakarai division which extends from Adam's Bridge to Vaippar, the central or Tuticorin division extending from Vaippar to Manapad and the southern or Kanyakumari division from Manapad to Kanyakumari. The Central division is the most productive one.

Thirty eight pearl fisheries only were conducted in the Gulf of Mannar in the period between 1663 and 1961 (Chacko, 1970). A characteristic feature of these fisheries is their irregular nature, a fishery sometimes being conducted after an interval of a number of decades. This is due to the pearl banks being poor in pearl oysters for a number of years. The gross revenue from pearl fisheries conducted in various years shows marked differences (Table XIV).

Table XIV

Revenue from the Pearl Fisheries in the Gulf of Mannar in the period 1900–1961 (after Chacko, 1970).

Year of Fishery	Gross Revenue (Rupees)
1900	19,461
1908	10,218
1914	16,542
1926 February–March	2,25,498
1926 November–December	31,387
1927 February–April	2,54,497
1927–28 November–January	1,95,039
1928 March–April	2,02,575
1955 March–May	1,46,138
1956 February–March	44,795
1957 March–May	1,68,807
1958 March–May	4,74,096
1959 February–May	8,65,130
1660 March–May	2,53,339
1961 March–April	3,18,234

The fluctations in the abundance of pearl oysters on the pearl beds in different years has been attributed to various factors like the presence of predators and pests, differences in hydrological characteristics, occasional silting, availability of breeding pearl oysters in sufficient numbers and successful spatfalls. The pearl banks off Tuticorin are only sparsely populated at present.

The pearl fisheries along the Indian coasts of the Gulf of Mannar are conducted by the Department of Fisheries of the Government of Tamil Nadu. A fishery is announced after a preliminary inspection when sufficiently dense populations of pearl oysters of fishable size are found on the pearl banks. Elaborate arrangements are made for conducting a fishery and a pearl camp is organised by the Govenment with the help and co-operation of divers, owners of boats, their crew and pearl merchants. On each day during the season which lasts for about two to four months, the pearl fishing boats with the divers leave the camp early in the morning hours for the pearl fishing grounds. If the wind is not favourable for the boats to sail they are towed to the fishing grounds by the inspection launches. On reaching the fishing grounds, the divers descend into the waters, being helped by sinking stones. Mahadevan (1971) has described the mode of diving practised by the divers of Tuticorin. Each diver quickly collects as many oysters as possible and comes up with the catch. The divers do skin-diving and hence cannot remain under water for more than $1\frac{1}{2}$ minutes for each dive. The diving operations are continued till about mid-day when they leave the grounds and return to the camp. Each diver gets a third of the catch of the oysters as his wages, but out of this he surrenders a part to the boat owner and the crew. The remaining two thirds of the catch is the Governmental share, which is auctioned late in the evening in lots of thousand oysters each. The merchants who buy the oysters remove them to the special enclosures where they are allowed to rot for sometime so that the tissues become softened, then washed and the pearls are carefully recovered. The divers and the boatmen sell their share of oysters by retail. The fisheries are operated from Tuticorin to harvest oysters from the richly productive central zone of the pearl banks.

A pearl fishery with rather a poor yield was conducted off Tondi in the Palk Bay in 1914, but the area has since then showed only stray oysters on scattered submerged objects on loose muddy sand.

In the Gulf of Kutch the pearl fishery is conducted by the Gujarat Government once in two or three years. The pearl banks known locally as 'khaddas' are located along the southern coast of Jamnagar District (Hornell, 1909 a; Easwaran *et al*, 1969). The divers are paid 25 paise for each oyster they bring. The income from the Gulf of Kutch fishery is small as compared to that of the Gulf of Mannar. The value of pearls fished in the years 1960-61 and 1961-62 has been estimated to be Rs. 6,005. In the year 1966-67 30,000 pearl oysters were fished in the Gulf (Easwaran *et al*, *loc. cit.*)

Pearls and pearl formation

The name pearl has originated according to Zeigler (as quoted by Bolman, 1941) from the Latin root 'pirula' meaning pear, due to natural pearls being often pear-shaped. Any concretion secreted by a mollusc may be called a pearl, though by pearl only the lustrous nacreous gems secreted by the pearl oysters are meant. Pearls are recognised as different types according to their composition. Periostracal pearls consisting of periostracal layers around a central nucleus, are brown in colour and do not have have any lustre (Hornell, 1922a). In porcellanous pearls the concentric layers are porcellanous e.g., those secreted by edible oysters, the sacred chank *Xancus pyrum* and the conch *Strombus gigas*. Hypostracal pearls are minute and found in the place of insertion of pallial and adductor muscles. True gem pearls are composed of concentric layers of iridescent nacre consisting of fine aragonite crystals, embedded in an organic matrix called conchiolin. Nacreous pearls are usually formed in the region between the pallial line and the border of nacreous layer of the shell of the pearl oyster. Several theories have been put forth at various times to explain the mode of formation of pearls. Careful studies have shown that the outer epithelial cells of the mantle of the pearl oyster secrete nacreous matter around foreign particles when they cause irritation to the soft body of the oyster. The foreign matter may be a sand grain, organic or inorganic debris or microscopic structures like cestode larvae. The mantle forms a pouch like epithelial sac around the intruding particle and there is secretion of nacre in concentric layers resulting in course of time in a pearl.

In Bombay markets four varieties of Indian pearls are recognised as reported by Ranganathan (1964) viz., 1. *Jeevan* — in which the pearl is perfectly spherical in shape, has bright lustre and the colour is rosy, pink or pinkish-white 2. *Gholwa* — the pearl is nearly spherical, lustrous with colouration of varying shades, 3. *Ghat* — small, irregular pearls and 4. *Masi* — very small sized ones.

Pearl culture

The Japanese have succeeded in evolving a method of culturing perfectly spherical pearls. There is controversy as to who exactly among the Japanese workers first produced the spherical culture pearl. It appears that credit for the achievement should go to Mise and Nishikawa (Cahn, 1949). Mikimoto improved upon the method and established an industry for manufacture of culture pearls in amazingly large quantities and earned the title of 'Pearl King'.

In the Japanese method a small piece of pearl oyster mantle is grafted carefully along with a spherical shell bead as the nucleus into a pearl oyster in between the lobes of the gonad. The operation is completed within a couple of minutes but it requires dexterity. The beads forming the nuclei are manufactured

from the hard shell of lamellibranchs like *Pleurobema* and *Megalonais* which Japan imports in large quantities from U.S.A. The operated oysters are reared in farms in calm shallow bays and looked after with great care. In the farm the oysters are kept in cages hanging from rafts at a depth of a few feet down from the surface water. The secretion of nacre commences at the end of one or two weeks. Small sized culture pearls are formed in a period of six months and large ones in two to three years. The pearl oysters reared in the farms are cleaned thrice or four times in a year to remove pests like sponges, barnacles, ascidians etc. which settle on them. For successful pearl culture the availability of adequate quantities of pearl oyster spat, careful rearing of them, careful implantation of the nucleus, protection of treated oysters under favourable environmental conditions like optimum ranges of temperature, salinity and light intensity, availability of food organisms, absence of strong currents and absence of pests and predators are essential.

70% of the culture pearls produced in Japan come from the pearl farms in Ago Bay in Mie Prefecture. The total annual production of culture pearls in Japan amounts to 25,000 Kan (1 Kan = 3·75 Kg). A major portion of this (more than 80%) is exported to a number of countries like U.S.A., West Germany, Hong Kong, Switzerland, Australia, India, Spain, France, Canada etc. India imports about 2,400 Kan of pearls annually from Japan (Alagarswami, 1970). Japan which is the foremost producer of culture pearls in the world has also helped other countries like Australia, Philippines and Hong Kong to set up pearl culture industries.

Culture pearls are classified into three kinds nacreous layer pearls, prismatic layer pearls and organic layer pearls (Wada, 1970) based on their composition. The nacreous layer pearls only are valuable as gems. Perfectly spherical and drop-shaped culture pearls are esteemed highly. The pearls exhibit a wide variety in colour and lustre which is due to differences in the pigment contained and superficial and laminar structures of the nacre. In addition to well known pearls of silvery sheen, there are rosy, pink, black, yellow and blue pearls. Environmental conditions like water temperature and light intensity in the farming area have been shown to influence the quality of pearls (Cahn, 1949).

About thirty years ago attempts were made by the Department of Fisheries of the erstwhile Madras State to rear the pearl oysters and induce them to form pearls (Devanesan and Chidambaram 1956, Devanesan and Chacko 1958). The oysters were successfully reared in cages in the vicinity of the Krusadai Island and secretion of nacre around the introduced shell beads was observed but spherical culture pearls were not formed. The techniques of pearl culture are better understood now than ever before. The local species *P. fucata* is very much like the Japanese oyster *P. martensii* and in fact it is doubted whether it is a variety of *P. fucata*. The Indian species has been found to be tolerant to farming conditions

and the prospect of culturing pearls employing this is bright although it may involve some initial trials attended with failure. If culture is taken up at least on a small scale, it would ensure a sustained supply of culture pearls and reduce fishing pressure on the natural beds the yields from which for natural pearls as pointed out are erratic and very irregular.

PEARL OYSTERS OTHER THAN *P. FUCATA* FROM INDIAN WATERS

In addition to *P. fucata* as stated earlier five other species of pearl oysters occur on the Indian coasts. The following is extracted from the senior author's earlier account on the subject (Rao, 1970).

Pinctada margaritifera (Linnaeus)

Synonyms

Mytilus margaritiferus Linnaeus 1758
Avicula magaritifera Reeve 1857
Pteria (Margaritifera) margaritifera var. *typica* Jameson 1901
Margaritifera margaritifera Hornell 1922a
Pteria margaritifera Gravely 1941
Pinctada margaritifera Prashad 1932, Prashad and Bhaduri 1933, Hynd 1955, Satyamurthy 1956, Rao 1970

Common name

English - *Black lip.*

Description

The hinge is devoid of teeth and much shorter than the width of shell. Anterior border of the body of shell extends far in advance of the anterior ear lobe. Byssal notch is broad. Anterior ear is well developed, posterior ear and posterior sinus are absent. Posterior end meets the hinge almost at right angles. Shell valves are moderately convex. The general colouration externally is dark grayish brown with a greenish tinge and with radially distributed white spots. These spots represent the basal portions of the successive growth processes. The nacreous layer is iridescent with a silvery sheen for the most part except distally where it is sooty black in colour. The non-nacreous border is very dark, sometimes with faint markings. Due to the dark marginal colouration this species is called 'Black lip'. The width of the nacreous region at the hinge about two-thirds of of the same in the broadest region of the valve (Fig. 10 A-D).

Jameson (1901) has distinguished several varieties under this species viz., *P. magaritifera* var. *typica* presumbly from Malay Archipelago, var. *zanzibarensis* from the east coast of Africa, var. *persica* from the Persian Gulf, var. *erythraensis*

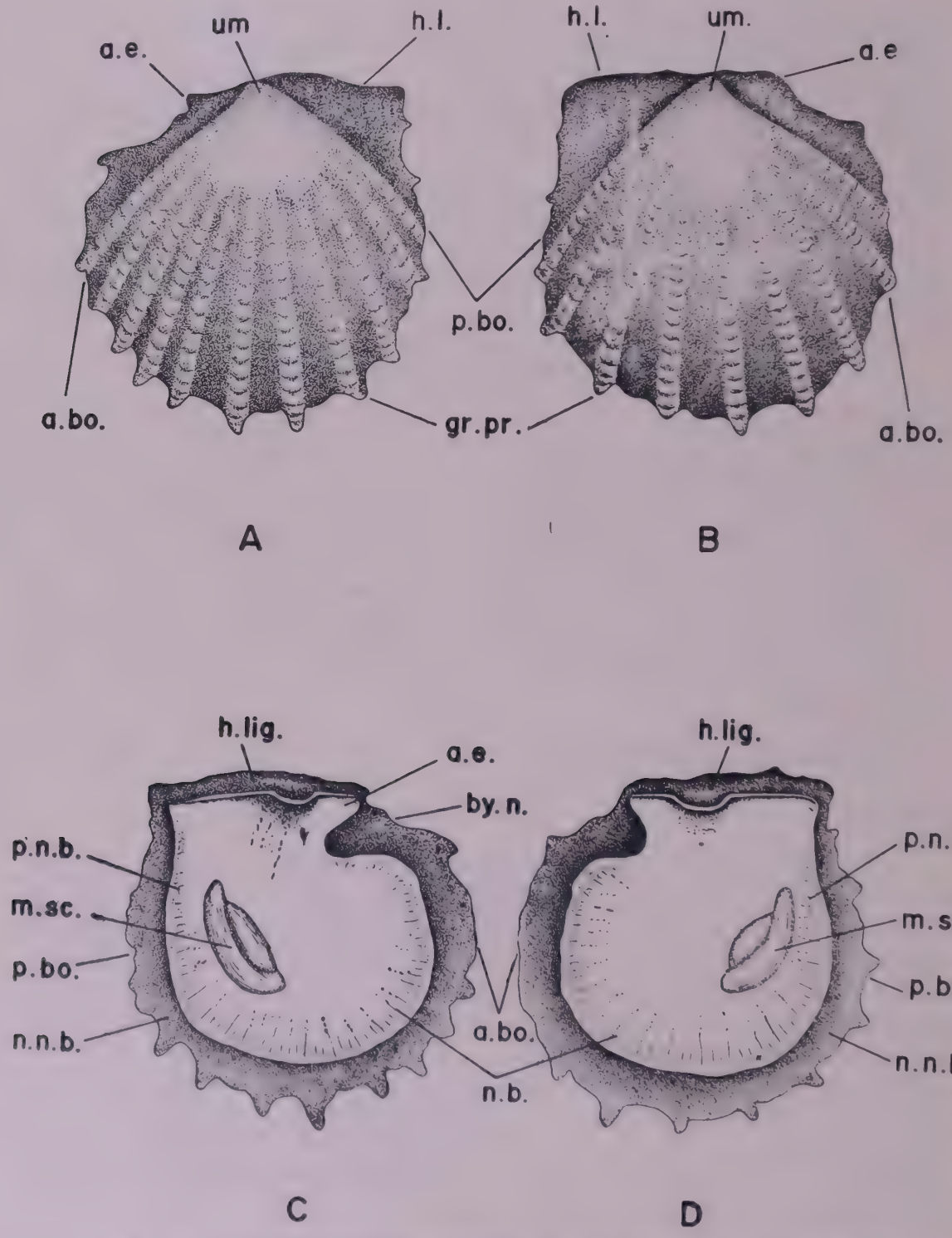

Fig. 10. *Pinctada margaritifera* (Linnaeus). A. Left valve outer surface. B. Right valve outer surface, C. Left valve inner view. D. Right valve inner view (after Rao, 1970) Lettering as in Fig. 8.

from the Red Sea, var. *cumingi* from the Eastern Polynesia and var. *mazatlanica* off Panama (Mazatlan etc.). These varieties are well known in commerce as Zanzibar shell, Panama shell etc. But some of these so called varieties so closely resemble the var. *typica* except in size and colouration that the distinction into varieties has been pointed out to be doubtful (Prashad and Bhaduri *loc. cit.*).

Distribution

It is widely distributed throughout the Indo-Pacific region.

This species is sparse on the Indian coasts. It yields good quality pearls and is utilized in Japan and Australia in pearl culture. It supports important mother-of-pearl fisheries in the Persian Gulf, Red Sea, south-western part of the Indian ocean and the Pacific Ocean.

Reproduction

The structure and development of gonads and reproductive cycles of this pearl oyster have been studied by Tranter (1958d) in the Torres Strait area Australia. Both protandry and protogyny were observed. Gametogenesis takes place in September and the gonads thereafter ripen and this is followed by limited spawning between October and December and intensive spawning in early January. The gonads are in the recovering phase in February and exhibit active gametogenesis and ripening in March. There is again restricted spawning in the period April – June, heavy spawning in July and the gonads are either in shrunken or recovering phase in August. This species has two spawning seasons in a year with some breeding activity in the intervening months The breeding periodicity of this species occurring in the Indian waters is little known.

Pinctada chemnitzii (Philippi)

Synonyms

Concha magaritifera laevis Chemnitz 1785
Avicula atlantica var. *B.* Lamarck 1819
Avicula chemnitzii Philippi 1849
Avicula pretexta; *A. tegulata* Reeve 1857
Avicula (Meleagrina) chemnitzii Dunker 1872
Pteria (Margaritifera) pretexta; P. (M) chemnitzii;
P. (M.) tegulata: Jameson 1901
Pteria chemnitzii Gravely 1941
Pinctada chemnitzii Prashad and Bhaduri 1933, Hynd 1955
Pinctada chemnitzii Rao 1970

The first authentic description of this species under the name *Avicula chemnitzii* was by Philippi (1849) from the China Sea. Reeve's *A. tegulata* of

Moreton Bay is identical with this species, but the name *tegulata* of Reeve being preoccupied by *tegulata* of Goldfuss (1836), Iredale (1939) as cited by Hynd (*loc. cit.*) has named it *P. epitheca*. The Philippine shell, *Avicula pretexta* of Reeve (1857) is also synonymous with this species. Prashad and Bhaduri (1933) recorded it for the first time from the Indian coasts.

DESCRIPTION

The shell is very similar to that of *P. fucata* except that the posterior ear is better developed and the convexity of the valves is much less. The anterior ear is well developed and the byssal notch is slit-like The hinge line is almost as long as the longest antero-posterior measurement of the valves. Both the anterior and posterior hinge teeth are present, the former small and rounded and the latter large and well developed like a ridge starting a little in advance of the posterior region of the hinge ligament. Correlated with the greater development of the posterior ear, the posterior sinus is very conspicuous.

The valves are externally reddish-brown with about four or more whitish or cream yellow radial markings from the umbo to the margin of the shell and the growth processes are rather broad. The nacreous lining is bright and lustrous and is developed to a far greater extent in the left valve than in the right valve and in the latter this border meets the hinge line obliquely outwards. The non-nacreous border is brownish without any conspicuous blotches of the kind met with in *P. fucata* (Fig. 11 A-D).

The pearl oysters are known to grow to about 10 cm in dorso-ventral axis.

DISTRIBUTION

On the Indian coasts it occurs in Tranquebar, Madras Harbour, Tuticorin pearl beds in Gulf of Mannar, in Palk Bay and off Balassore coast (Orissa). Outside India it has been recorded in Ceylon, Aden, Mergui Archipelago, Penang, Indonesian group of Islands, Australia, Hong Kong, Philippines, China Sea and Japan.

PINCTADA SUGILLATA (Reeve)

SYNONYMS

Avicula fimbriata; A. sugillata; A. irradians; A. chamoides Reeve 1857
Pteria (*Margaritifera*) *sugillata* Jameson 1901
Meleagrina sugillata Hedley 1910
Pinctada albina sugillata Hynd 1955
Pinctada sugillata Hedley 1916, Prashad 1932, Rao 1970

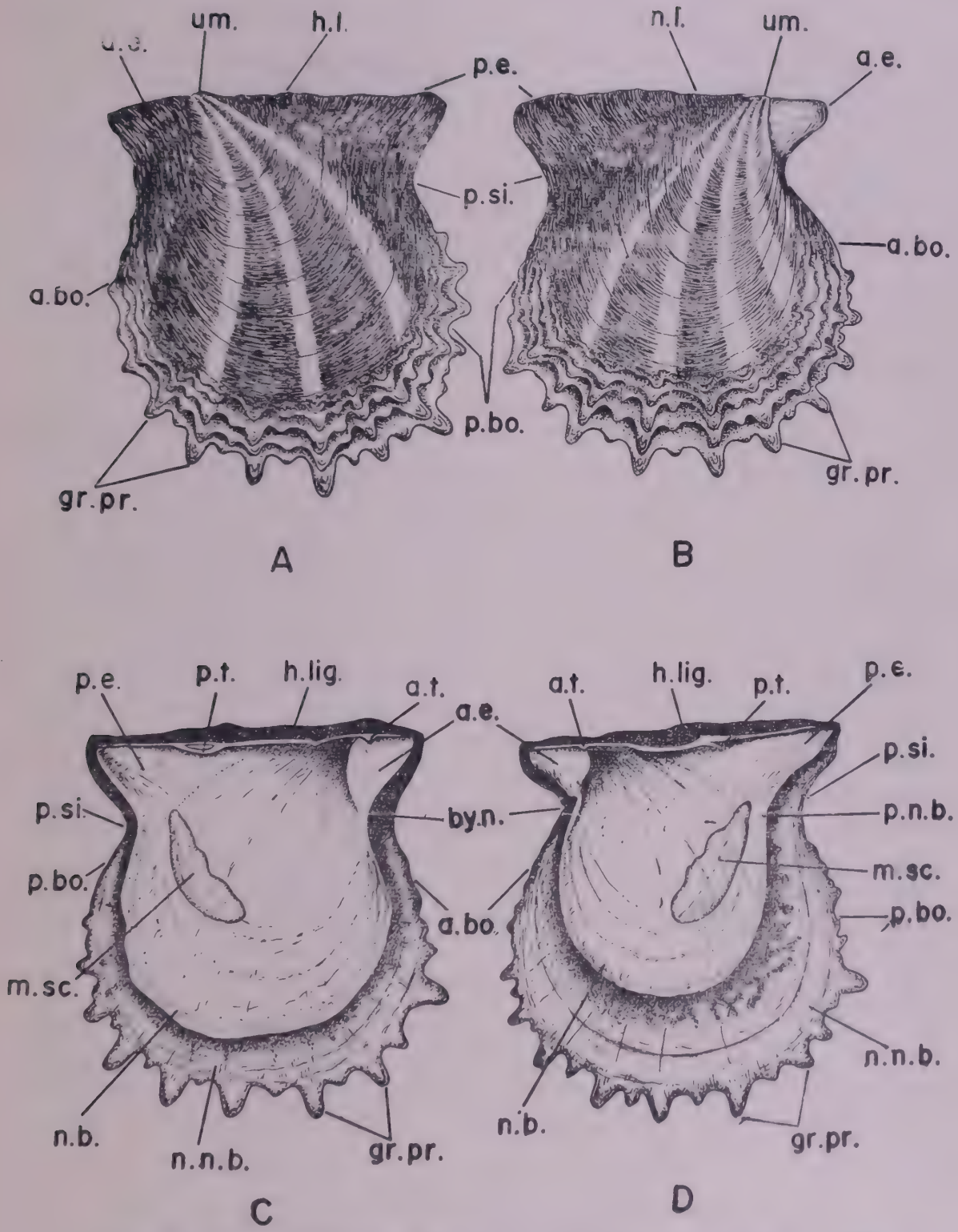

Fig. 11. *Pinctada chemnitzii* (Philippi). A. Left valve outer surface. B. Right valve outer surface. C. Left valve inner view. D. Right valve inner view (after Rao, 1970). Lettering as in Fig. 8.

Jameson (1901) considered *Avicula fimbriata*, *A. sugillata* and *A. irradians* of Reeve (1857) to be synonymous. The species *fimbriata* has page priority but is preoccupied by *A. fimbriata* of Dunker (1852) which is recognized as a valid and distinctly separate species by Jameson (1901) and Hynd (1955). *A. chamoides* of Reeve (1857) has been stated to be only a young specimen of *A. sugillata* (Hynd, *loc. cit.*). Prashad (1932) considered *Meleagrina albina* of Lamarck (1819) to be synonymous with *Pinctada vulgaris* of Schumacher, but Hynd recognized it as a valid species synonymous with *P.* (*M.*) *carcharium* a name given by Jameson (*loc. cit.*) to the Shark Bay shell. Hynd considers two varieties under *Pinctada albina* viz., *sugillata* (Reeve) and *carcharium* (Jameson).

Description

The hinge is very much shorter than the widest antero-posterior axis of shell, they being in the ratio of 1:1·3. The antero-posterior measurement is almost equal to the dorso-ventral measurement. The anterior ear in both valves is small and the byssal notch is a moderately wide slit. The anterior ears are slightly bent towards the right so that the hinge line when viewed from the top, is seen to be deflected anteriorly to the right side. This character recorded by Hynd (1955) in Australian shell is prominent in the Indian shell. The posterior border of the shell shows a small, not well-defined sinus which is correlated with the very poor development of the posterior ear. The convexity of the valves is not marked, particularly that of the right valve which is only moderately convex. The hinge teeth are present but inconspicuous in the adult specimens examined, the anterior one being roundish and small and the posterior one seen as a streak. The colouration of the valves for the most part from the hinge and extending over the body of the shell is dark gray with a tinge of brown. The lower and posterior regions of the valves are light yellow and gray. There are about six yellowish radial markings starting from the umbo and extending towards the margin. The nacreous region on the inner surface of both the valves is well developed. Posteriorly the nacreous border as it meets the hinge line presents a wavy course. Hynd has stated that the nacreous region is bounded by a narrow black band on the non-nacreous border, but this was noticed only in one of the two specimens examined (Fig. 12 A-D).

A well-shaped shell from the pearl oyster beds of Tuticorin measured 5·5 cm in hinge length, 7·1 cm in widest antero-posterior axis and 7·2 cm in the dorso-ventral axis.

Distribution

This species occurs in Australia, Indonesian group of Islands, India and Celebes. The species has been recorded in India at Tuticorin and Madras harbour.

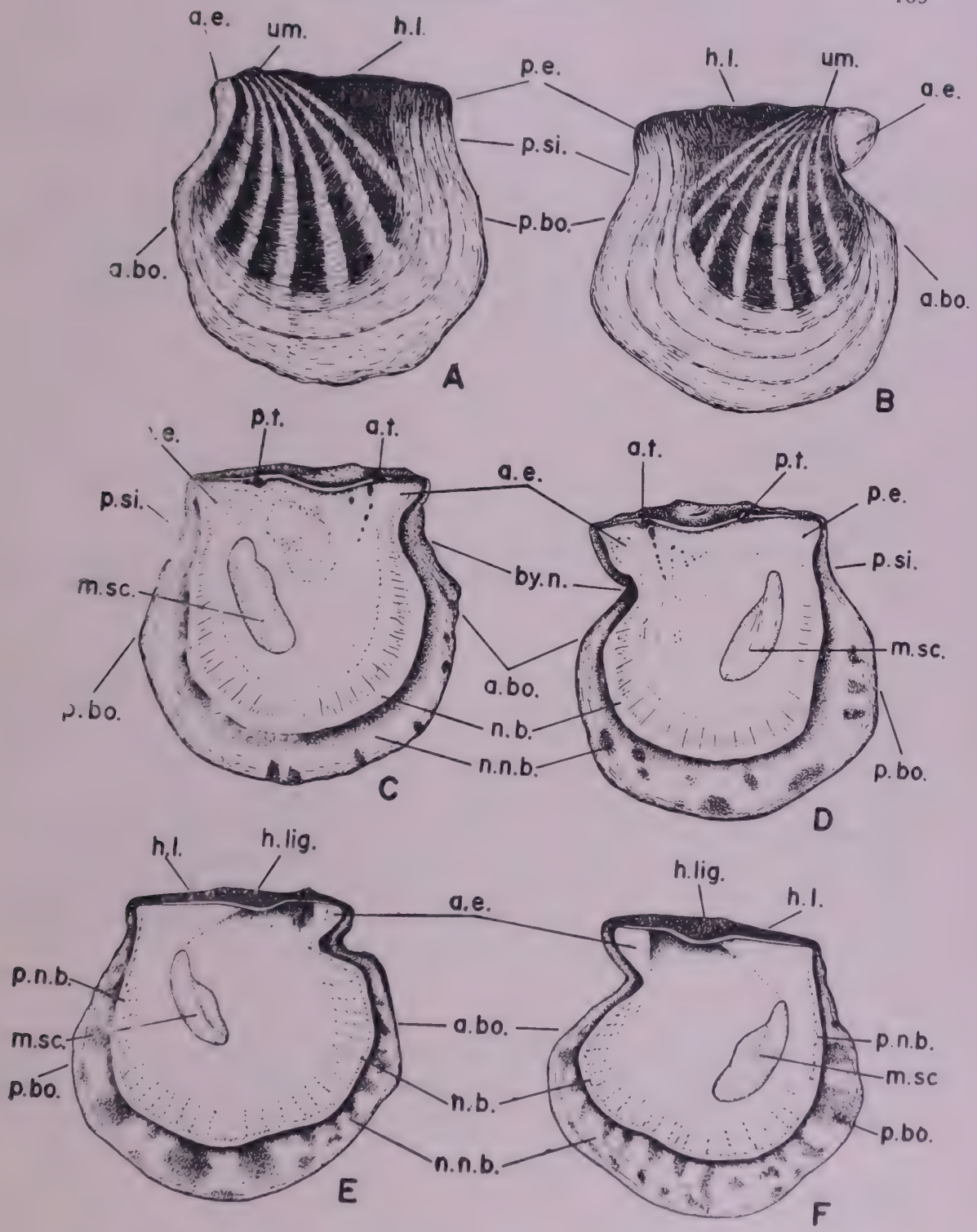

Fig. 12. *Pinctada sugillata* (Reeve). A. Left valve outer surface. B. Right valve outer surface. C. Left valve inner view. D. Right valve inner view. *Pinctada anomioides* (Reeve). E and F. Left and right valves inner view (after Rao, 1970). Lettering as in Fig. 8.

Reproduction

Tranter (1958 a, b, c) has studied the structure of the primary gonad and adult gonad and reproductive cycles in Australia. The primary gonad consists of a paired system of confluent tubules (follicles) opening to the exterior by laterally situated urino-genital openings. The primary gonad does not have morphologically differentiated gonoducts. The adult gonad is of cream colour in the male and yellow in female and covers the stomach, associated digestive diverticula and gut loop, Sexual maturity is attained within six months. There is a major spawning period in the autumn. Spawning is frequently partial and there is phagocytosis of unspawned germ cells.

Pinctada anomioides (Reeve)

Synonyms

Avicula anomioides Reeve 1857
Avicula (*Meleagrina*) *anomioides* Dunker 1872
Pteria (*Margaritifera*) *anomioides* Jameson 1901
Pinctada anomioides Prashad 1932, Prashad and Bhaduri 1933, Rao 1970

Description

The hinge line is shorter than the width of the broadest region in the antero-posterior axis, they being in the ratio of 1:1·2–1·5. The hinge line and the dorso-ventral axis are in the ratio of 1:1·4. Hinge teeth are absent or faintly visible. The antero-posterior axis of the body of the shell extends to some distance in front of the vertical line to the external border of the anterior ear. The anterior ear is very moderately developed and presents a deep byssal notch at its base. The posterior ear and the posterior sinus are absent. Externally the valves are yellowish with a light tinge of gray. Faint radial markings are present. The valves are translucent. The nacreous region is well developed and its posterior border meets the hinge at right angles (Fig. 12 E-F).

Distribution

In India it is recorded from Bombay, Madras, Mandapam (Palk Bay), Tuticorin and Andaman Islands. Outside India it has been recorded off Aden, Ceylon, Mergui Archipelago and the Indonesian group and the nearby Islands.

Pinctada atropurpurea (Dunker)

Synonyms

Avicula (*Meleagrina*) *atropurpurea* Dunker 1852, Dunker 1872
Pteria (*Margaritifera*) *atropurpurea* Jameson 1901
Pinctada atropurpurea Prashad and Bhaduri 1933, Rao 1970

Description

The shell is roundish with a narrow hinge. The valves are thin, translucent, copper coloured and moderately convex. The byssal notch is deep. The nacreous layer is thin and extends to a greater portion of each valve. The posterior nacreous border meets the hinge line at an acute angle. A trace of an anterior hinge tooth may be present in some shells. Prashad and Bhaduri (1933) state that this species is closely allied to *P. anomioides* but distinguishable from the latter by its copper red colouration, thinner and more translucent valves and the posterior nacreous border meeting the hinge line at an acute angle.

Distribution

On the Indian coasts it is known from the Madras harbour and Andaman Islands. Outside India it has been recorded from Ceylon, Mergui Archipelago and the Philippine Islands.

A specimen obtained from the Madras harbour measured 3·7 cm in hinge line, 4·2 cm in the broadest region of the shell in the antero-posterior axis, 4·5 cm in the dorso-ventral axis and 1·9 cm in thickness.

VII ECOLOGY OF PEARL OYSTER AND CHANK BEDS

S. Mahadevan and K. Nagappan Nayar

The Gulf of Mannar and the Palk Bay zones of the southeast coast of India, the Halar coast of the Gulf of Kutch especially the reefs of Sachana, Salaya, Piroton, Ajad etc. and a narrow strip in the extreme southwest coast of India from Colachel to Trivandrum are all places where either the chanks or the pearl oysters or both occur in fairly large numbers. In addition to the above, chanks occur along the Coromandal coast upto Madras although this stretch is of minor importance. In some places in Andamans also chanks occur in limited quantities. Of all the places the most productive areas, as far as the pearl oysters are concerned, are located in the Gulf of Mannar and very rich chank beds exist both in the Gulf of Mannar and in the Palk Bay. Naturally much attention has been focussed on these two regions to study the fisheries and ecology of these two commercially important molluscs as evidenced by the works of Hornell (1914, 1916, 1922a), and Mahadevan and Nagappan Nayar (1966, 1967, 1968). Very little is known about the other areas except for Hornell's report (1909) on the marine biology of the Okhamandal coast of Kathiawar.

Herdman's reports (1903–1906) deal with the pearl fisheries and the fauna of the pearl oyster beds, exclusively of the Gulf of Mannar along the Ceylon coast and Thurston (1896) and Hornell (1922a) have given the first evaluation of the faunistic condions of the paars in the Gulf of Mannar of the Indian coast. It appears that the faunistic and topographical features are identical for both the coasts While writing about the Ceylon oyster beds it was opined by Hornell (*vide* Herdman, 1905) that considerable changes take place periodically in regard to the sea-bottom there. If so the same might apply to the paars along the Indian coast also. It was not known whether any such notable changes had taken place in the long interval that had elapsed since Hornell (1922a) published his hypothetical diagrams of shapes of the pearl oyster beds and chank beds along the Indian coast of the Gulf of Mannar and if so to what extent. Therefore it was deemed necessary to undertake a survey of the sea-bottom of the most productive zones on scientific lines to chart the locations and extent of the paars and chank grounds and also to study the general ecological features. For this purpose direct underwater observations by Aqualung diving were undertaken by the authors between 1962–64 and again from 1968 onwards. In addition to the

above regular programme of work it was also possible to study the conditions of the pearl oyster beds and chank beds in the Palk Bay zone also, although restricted to cursory surveys, especially off Rameswaram and Tondi since periodical rumours were set afloat by the local fishermen that pearl oysters existed in great abundance in these areas.

The following account is the summary of the observations thus made and gives a picture of the ecological conditions as they exist now. Underwater photographs taken during the studies are given in Pl. I A-D and Pl. II A-D.

ECOLOGY OF PEARL OYSTER BEDS

A. Gulf of Mannar zone

The submarine plateau of the Gulf of Mannar bordered for the most part by the 15 to 25 m line widens greatly in the northern part of the Gulf as it approaches Pamban. This surface of the plateau is mostly sandy with outcrops of the rock or paar generally in the form of flat or slightly inclined ledges, occasionally forming low terraces, sometimes level with the surface and sometimes a few cm below it, the rock being then covered with either a thin or a thick layer of sand as the case may be. Right from Cape Comorin up to Pamban, at the head of the Gulf, there are about 65 paars (Hornell, 1922a). Many are extremely small and known to be only about a few hundred sq. metres in area. They owe their separate entities to the detailed local knowledge of the fishermen engaged in ordinary fishing. Hornell (*op. cit.*) divided these paars into 3 divisions viz., Northern or Kilakarai, extending from Adam's Bridge to Vaipar, the Central or Tuticorin from Vaipar to the latitude of Manapad and the Southern or Comorin from thence southwards to Cape Comorin. Of these, the central division is by far the most important in view of the fact that out of the 40 pearl fisheries that had taken place between 1663 and 1961 all but one fishery had been in the paars located in this division. Further this division contains paars of larger extent and hence have produced most of the recorded fisheries. Hornell's (*op. cit.*) diagrams of the paars of this division (Fig. 13 A and B) show the approximate disposition and extent of the various paars in this area. The paars in other divisions are considered as unimportant since most of them are unproductive and are always covered by turbid waters even during the most favourable season with long swells at the bottom throwing up the bottom silt in suspension with the consequence that the area constitutes a negative force for the healthy survival of pearl oysters. Therefore in order to get an idea of the typical conditions of the oyster beds the central division (Fig. 14) was first chosen for the study.

As already explained the widening of the plateau in the north allows the paar in the central division to form two series from Manapad northwards upto

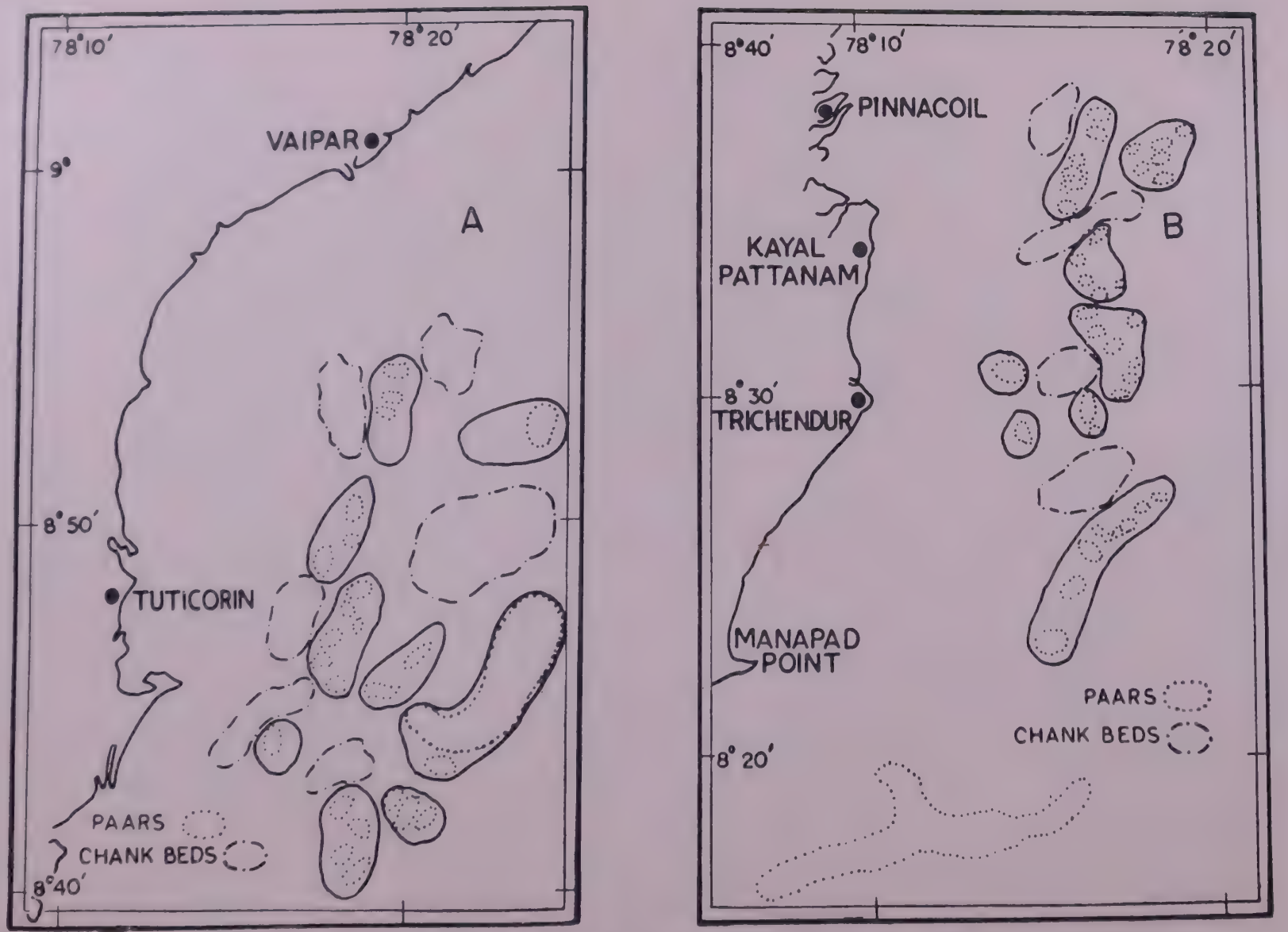

Fig. 13. Showing the paars and chank beds as given by Hornell (1922a) for the region 8°00′ N lat. and 9°00′ N lat. A. Chart of the northern half of the Central division. B. Chart of the southern half of the Central division.

Vaipar, one in shallow water from 10–14 m and the other at 19–23 m roughly parallel with the coast, the inner being at about 9 km distance from the coast and the outer 18 km from land.

The general physical and faunistic features of the paars lying on the inner series within 14 m range appear to be same throughout. However, here and there interesting differences do occur. The sea floor is essentially of sand grains of coarse nature, but broken up by multitude of rocky outcrops of loose blocks of calcrete of various sizes; elsewhere there are fragments of corals black or brownish in colour.

Dead shells with rounded–off edges mixed with bits of *Porolithon* sp. and *Halimeda* spp. are also found. In some areas the rock may be of grit stone cemented by carbonate of lime as in the area off Manapad. In the northern areas, however, very often the eastern fringe of the paar is seen very distinctly, especially in the areas off the small islands north of Tuticorin well-demarcated because of the elevated rocky edge dropping vertically down to the adjacent sandy ground, the deep undercuts of the shelfs of the rock sand interface housing lobsters and varieties of large-sized perches. It is also not uncommon to see laminated rocky flats devoid of crevices or fissures over which coarse sand is spread all over. Large drifted shells such as *Bulla* sp., *Pinctada fucata* (Gould), *Pecten* spp., *Arca* spp., *Anomia* spp. and *Turritella* sp., all in worn out state, make up the coarse material. In addition to these, foraminifers of *Textularia* sp., *Pulvulina* sp. and *Heterostegina* sp. are commonly found intermingled.

The area is subjected to heavy oscillations at the bottom always because of the nearness to the shore-line. The water over the beds is very often turbid even during fair weather. The proportion of mud in the sand is greater than in the outer series. This might be due to the vicinity of the embouchure of the Vaipar, Vembar and Tambaraparni rivers. This feature combined with the oscillation experienced in this area is likely to adversely affect the settlement and survival of the pearl oysters.

Characteristic of the area is the dense growth of sponges, especially in the northern Vaipar area. *Aulospongus tubulatus* (Bowerbank), *Phakellia donnani*, *Siphonochalina communis* (Carter), *Iotrochota* spp., *Clathria procera* (Ridley), *C. indica* Dendy, *Mycale grandis* Gray, *Zygomycale parishii* (Bowerbank), *Phyllospongia* spp., *Spongionella* spp., and *Suberites* spp., are abundant. Dense forest-like growth of the gorgonid *Juncella juncea* Pallas and *J. gemmacea* (Valenciennes) is noticed in the northern area.

The growth of the coral *Heteropsammia* sp. is characterstic of the inner series. *Montipora* sp. and *Echinopora* sp. are the other common corals in addition to *Porites* sp.

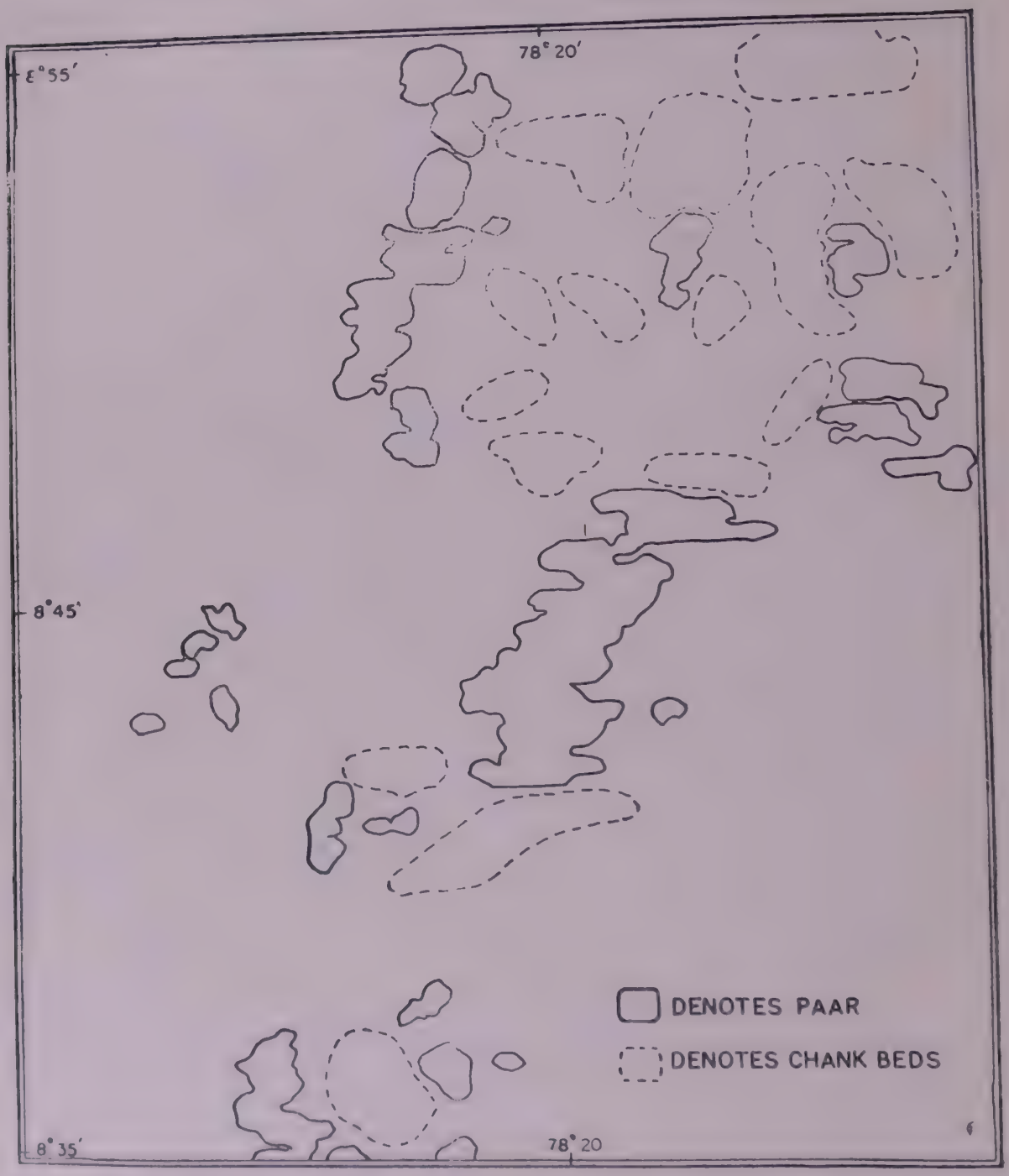

Fig. 14. Showing the paars and chank beds in the region between 8° 35′ N lat. and 8° 55′ lat. as they exist to-day.

The molluscan fauna is mostly represented by myriads of *Modiolus* spp. spreading like mattress on the bottom. Large *Pinna* spp. are found in good numbers rooted in thin layer of sand covering the rock in many places. *Cypraea tigrinus* are seen in rocky pits. *Oliva* spp., *Conus* spp., *Nassa* sp. and *Bulla ampulla* are the other common shells.

Among the echinoderms *Lamprometra palmata palmata* (J. Muller) and *Comanthus* (*Comanthus*) *timorensis* (J. Muller) were the most common living under rocky crevices and over the gorgonids and sponges. *Holothuria edulis* Lesson, *Protoreaster lincki* (Blainville) and tests of *Clyspeaster humilis* (Leske) are the most common.

The fish fauna is fairly rich and consists of *Scolopsis bimaculatus* Rüppell, *S. vosmeri* (Bloch), *Abalistes stellaris* (Bloch), *Upeneoides* spp., *Chaetodon* spp., *Pomacanthodes annularis* (Bloch) and *Lutjanus lineolatus* (Rüppell). Large fishes like *Gaterin* spp., *Enneacentrus miniatus* (Forsk), *Epinephelus* spp., *Lethrinus* spp. and *Siganus* spp. are abundantly seen.

The flora is poor in the southern area but in the Vaipar area *Gracilaria* spp., *Hypnea* spp. and *Sargassum* spp. are common.

Compared to the inner series the outer series is richer in fauna and flora qualitatively and quantitatively. The formation of the outer series runs in a southeast to northwest direction, generally between 15m–25 m depth range. The formations are fairly extensive stretches of rock whose outcrops differ greatly from tubular fragments, rock of a metre or two across to great areas of a km in extent. Fine grained sand covers the rock filling up the hollows and crevices occasionally cutting off the continuity of paars to give the impression of sandy bottom whereas actually the hard core of the bottom can be easily detected by removing the engulfing sand of 5–10 cm thickness. Live corals are seen as a low fringe running along the 18–19 m depth on the eastern side of the paar. Broken and worn out fragments of pearl oyster shells, cockles, *Pecten* spp., *Cardium* spp., *Conus* spp. etc. are scattered about in great profusion. Balls of *Porolithon* sp. from the size of a nut to that of a lime are seen on the edges of the rocky expanse. All through the length and breadth of the paar are a number of pits ranging from 0.5 – 1 m diameter and of equal depth. Such pits are inhabited by a number of small and large fishes, eels and lobsters. The general set–up of the area appears ideal for the settlement of oysters as the horizontal clarity at the bottom exceeds 15 m on most days and because of the variety of fauna and flora inhabiting the area.

The concentration of sponges is very high especially in the upper (northern) regions of the paar. The predominant species are *Petrosia testudinaria* (Lamarck), *P. similis* Ridley, *Aulospongus tubulatus* (Bowerbank), *Axinella donnani* (Bowerbank), *A. symmetrica* Dendy, *Spirastrella inconstans* (Dendy),

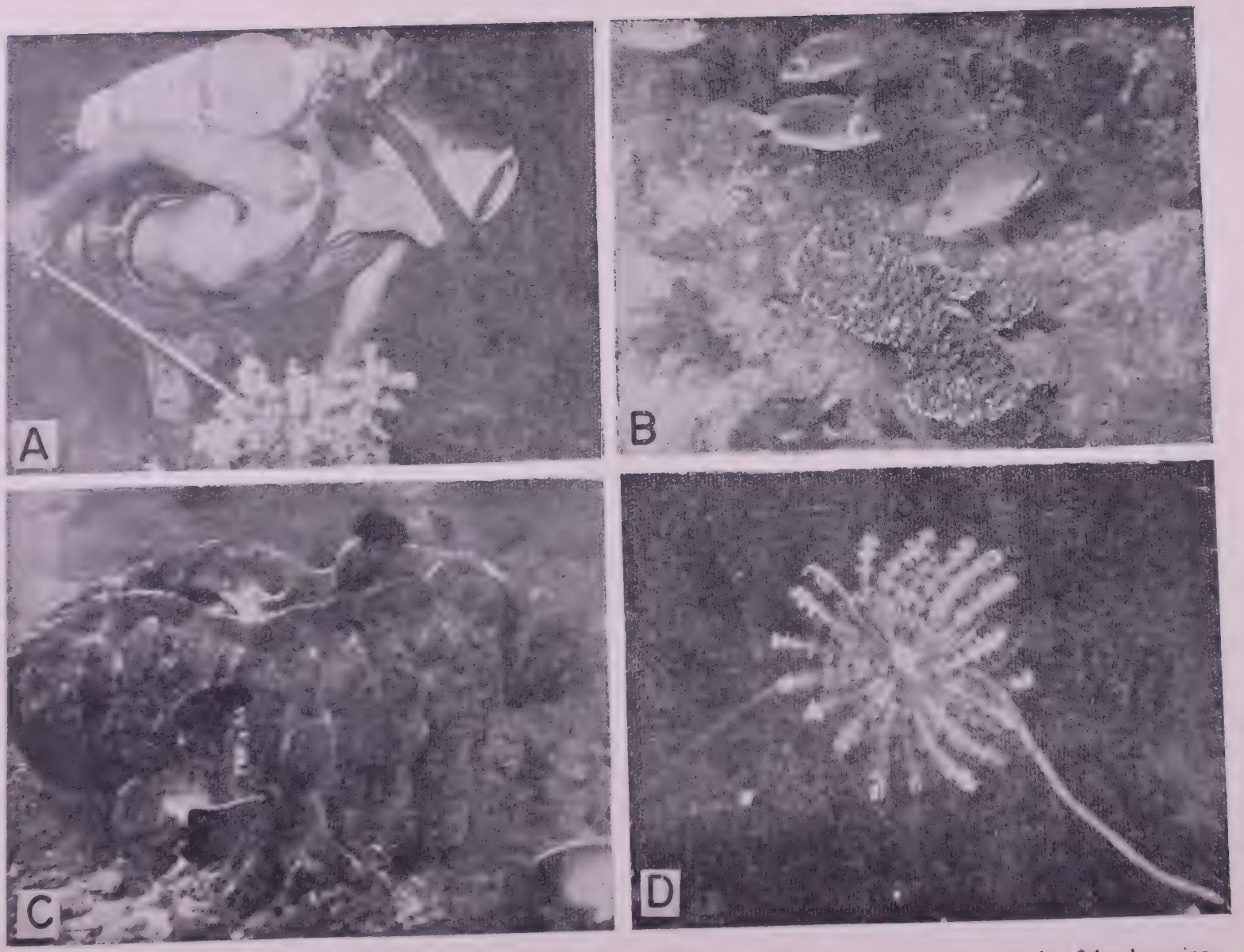

Plate I. A. Senior the author (S.M.) exploring the sea-bottom. B. Coral reef with *Scolopsis vosmeri* and other fishes hovering around. C. *Petrosia testudinaria* on a rugged paar with *Chaetodon* sp. around it. D. The Sea-lily *Lamprometra* sp. on the stem of a gorgonid.

Suberites spp., *Cliona vastifica* Hancock, *Clathria indica* Dendy, *C. procera* (Ridley), *Mycale grandis* Dendy, *Raspailia hornelli* Dendy, *Myxilla arenaria* Dendy, *Iotrochota purpurea* (Bowerbank), *Pachychalina subcylindrica* Dendy and *Phakellia donnani* (Bowerbank). There are other species of *Auletta, Spongionella, Hippospongia, Phyllospongia* and *Hircinia* met with in the 25 metre depth-line also.

The area is rich in coelenterates with a conspicuous growth of anemones, alcyonarians and gorgonids. Some of the fleshy alcyonarians that are common are *Sarcophytum* spp., *Lobophytum* spp. and *Sclerophytum* spp. *Spongodes rosea* Kukenthal. *Nepthya* sp., *Solenocaulon tortuosum* Gray, *Suberogorgia* sp., *Acanthogorgia* sp., *Lopohogorgia* sp. and the gorgonids. *Juncella juncea* Pallas and *J. gemmacea* (Valenciennes) harbouring many commensals are noticed commonly.

The area is rich in molluscan fauna. Noteworthy among the bivalves are *Pinna* spp., *Malleus* sp., *Cypraea* spp., *Murex* spp., *Sistrum* spp., *Nassa* spp., *Conus* spp., *Dentalium formosum* Adams and Reeve, *Pecten* spp., *Avicula zebra* Reeve on sea fans and *Pinctada fucata* (Gould) lying loose in crevices and fissures. *Modiolus* spp. are found settled down over the entire area covering the floor like a carpet. It is feared that this settlement of *Modiolus* spp. albeit a short period, might have deleterious effect on the existence of the general fauna itself, not to mention oysters. The observations of Herdman (1906), Hornell (1922) and Mahadevan and Nagappan Nayar (1968) are of interest in this regard. Shells of *Pteria penguin* (Roding) are seen in 25 m line. *Xancus pyrum* (Linn.) are also seen here and there.

A variety of ophisthobranchiate molluscs are seen in different habitats on seaweeds, on dead shell valves, on crinoids and on sand or underneath coral blocks. Species of *Eolis, Hervia, Discodoris, Halgerda, Phyllidea, Pleurophyllidea, Platydoris, Chromodoris* and *Philene* are seen commonly.

Octopus (*Polypus* spp.) are common in pits and holes. Great numbers of dead, empty broken shells are found in crevices and faults in the rocks haunted by the octopus. Pearl oysters are particularly preyed upon by them thus posing the question as to whether they are the chief enemies of the pearl oysters. On many occasions the octopus has been noticed to open the shell valves of the oysters and eat the flesh.

The echinoderm fauna is found to be lacking in abundance as a whole. By far the crinoids are the most abundant, found attached to the gorgonids, under coral blocks or on sponges. *Lamprometra palmata palmata* (Muller) and *Comanthus annularis* (Bell) are the most common. Among holothurians, *Holothuria edulis* Lesson is the most common. The synaptid *Chondrocloea striata* (Sluiter) is common in deeper waters. Of the sea stars, *Protoreaster lincki* (Blainville) is the

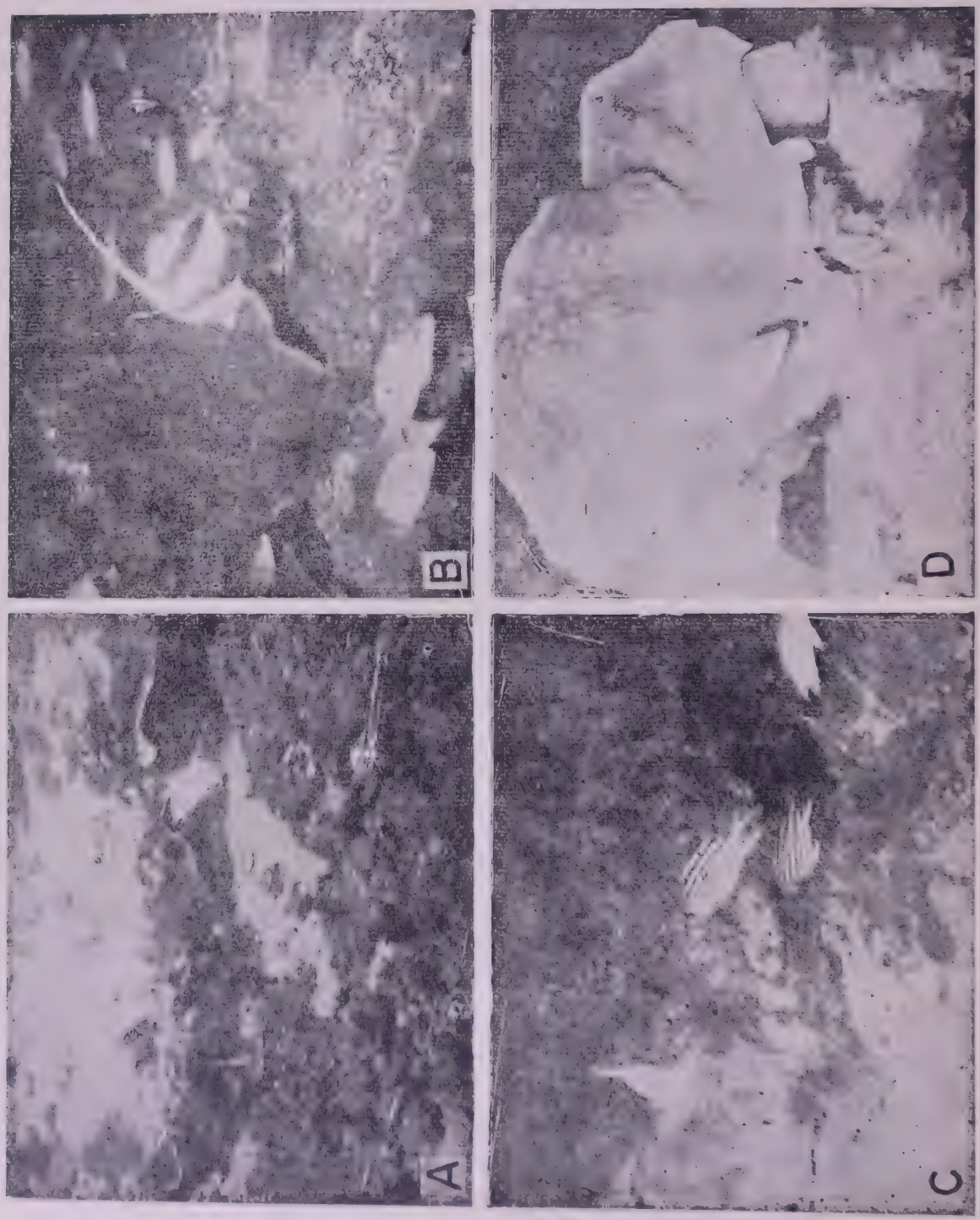

Plate II. A. Sand spread over paar. This type of bottom is common in the outer series of paars off Tuticorin
B. An inverted coral with *Heniochus acuminatus* and *Lutjanus kasmira* living around the area.
C. The Red soldier fish, *Holocentrus* sp. over a rocky crevice.
D. *Chaetodon* sp., *Scolopsis* and *Lutjanus* around a coral block.

most abundant although *P. affinis* (Muller and Troschel) and *P. australis* (Lutken) are also seen rarely. The southern areas are more thickly populated whereas in the north and shoreward areas there are only 2 per 100 sq. metres. The other sea stars are *Pentaceraster multispiralis* V. Martens, *Linckia laevigaeta* (Linnaeus) and occasional specimens of *Culcita schmideliana* (Retz), *Protoreaster nodosus* (Linn.), *Astropecten indicus*. Doderlein and *A. monocanthus* Sladen are also seen.

Of the cake urchins *Clypeaster humilis* (Leske), *Echinodiscus auritus* (Leske) and *Laganum depressum* Lesson are common. Of the heart urchins *Echinolampus ovata* (Leske) and *E. alexandri* de Lorial appeared here and there. Among sea urchins *Salmacis bicolor* Agass. and *Salmaciella dussumieri* (L. Agassiz) occur wherever dead coral blocks are covered by coarse sand. In the crevices of the coral stones and under the boulders live many numbers of ophiuroids of which *Astrob clavata* (Lyman), *Ophiocnida echinata* (Lungman), *Ophiocnemis marmorata* (Lamarck), *O. cataphracta* (Brock) and *Ophionereis dubia* (Muller & Troschel) are more common.

Fishes: All over the rocky bottom, fishes are found abundantly. Numerically *Abalistes stellaris* (Bloch), *Sufflamen capistratus* (Shaw), *Odonus niger* (Rüppell), *Scolopsis bimaculatus* Rüppell and *S. vosmeri* (Bloch) are the most abundant. But wherever the area is rugged with boulders and pits fishes like *Gaterin* spp., *Lethrinus* spp., *Enneacentrus* sp., *Epinephelus* spp., *Pomacanthodes annularis*, *Lutjanus sebae* (Cuvier), *Pterois miles* (Bennet), *Chaetodon* spp., *Zanclus cornutus* (Linn.) and *Heniochus acuminatus* (Linn.) live in large numbers.

Throughout the rocky expanse studied the density of algal vegetation seems to be moderate especially on the eastern edge between 17–25 m line. The flora on the southern areas seem to be luxuriant with *Sargassum* spp., dominating in most of the areas. Among the red algae *Gracilaria edulis* (Gmel.) Silva and *Hypnea valentiae* (Turn) are common. The other common species in the pearl banks of the outer series are *Caulerpa* (3 species), *Codium* sp., *Halimeda* spp., (2 spp.), *Dictyota* (3 spp), *Padina* spp., *Porolithon* sp., and *Spathoglossum* sp., It has been remarked by Prasanna Varma (1960) that the algal flora of the pearl beds is mostly of the types found in coral beds or rocky regions of Indian coast, irrespective of depths. In other words there appears to be no selectivity for algae with regard to depth.

Palk Bay zone

I) *Tondi area*: In addition to the pearl oyster beds in the Gulf of Mannar it has been stated (Hornell, 1916) that two distinct beds of oysters were present off Tondi in the Palk Bay also, a larger one for a distance of 8 km with a width of 0.8 km between Pasipattinam and Thondi in 10 m and a smaller one at 9 m off Karangadu. It was stated that no rocks occur there and all the oysters

were found attached to molluscan shells lying loose at the bottom. Never before has *Pinctada fucata* (Gould) been seen living in such an environment. In the Gulf of Mannar they are always found on continuously rocky ground or else in patches of intermingled stretches of rock and sand. A small fishery off Tondi was conducted by Hornell for 20 days in 1914. After this lone instance, so far no *P. fucata* have been collected from this area. Choodamani and Mahadevan (1962) investigated this area of the Palk Bay in 1958 and concluded that it would be a waste of time to inspect this area and that the grounds here cannot be considered as oyster beds in view of the extremely sandy nature of the bottom.

The area was studied for the faunistic features in 1968 by the authors in addition to the survey of the nature of the bottom. The bottom is of sand upto 7 metres, coarse sand and sand-built polychaete tubes in profusion upto 8.5 m and wavy furrowed sand track upto 11 m off Tondi. Shells of *Strombus* sp., *Melogina* sp. and *Murex tribulus* are the most abundant. *Xancus* pyrum (Linn.) are commonly seen in the coarse sandy areas where the polychaete tubes are abundant. *Clypeaster humilis* (Leske) and *Protoreaster australis* (Lutken) are the other inhabitants of the area in general. The beds off Pasipattinam are located at 7–10 metres depth aporoximately 4.5 sq. km in area, the bottom being muddy and sandy. Only one stray specimen of *P. chemnitzi* was obtained in this area. The bottom fauna is identical to that of Tondi area with the exception that the chank population is not evident. But the prolific numbers of *Salmacis bicolor* var. *typica* Martens and *Holothuria scabra* Jaeger and luxurious growth of colonies of *Lytocarpus* sp. and *Thirea* sp. on dead shells is very characteristic of this area. The area off Vattanam was reported to be rocky by the local fishermen. Survey of this region showed that there is an area of approximately 3 sq. km between 4 and 5.5 metres depth where the bottom is made up of sand and accumulation of dead coral pieces smoothened and rounded off due to wave action, lying loose intermingled with dead and worn-out shells of different species. But there is no evidence of any pearl oyster settlement in this area.

The physical features of the Tondi area are such that there is always turbidity over the bottom reducing the visibility to less than a metre. This factor is not quite conducive for the healthy survival of the pearl oysters even if they were to settle here by any chance. The beds cannot, therefore, be considered as pearl oyster beds.

II) *Rameswaram area :* East of Rameswaram, lying at 9 metres depth is a paar over which sand and mud have been deposited to 10 cm thickness. The area is about a sq. km and is populated by *Holothuria scabra*, *Salmacis bicolor* and few wormed chanks. Polychaete tubes are seen frequently. But there is no evidence of any pearl oysters living on the bed. Another paar north of this area at $9\frac{1}{2}$ metres depth is of flat rock bottom with considerble sprinkling of coarse

sand over the rocky substratum. The bottom fauna is typically that the of rocky area. *Suberogorgonia* spp., sponges specially *Suberites* sp., *Phakellia* sp., *Spongionella* sp., *Heteronema* sp., *Sigmadocia* sp., *Aulospongus tubulatus, Clathria* sp., *Axinella donnani* and *Spirastrella* sp. are seen commonly. But the area of the paar is very limited. Flanking the shoreward and seaward sides of this area are two stretches of paars of considerable width and length running north to northeast and south to southeast respectively at 9 metres depth. The bottom is hard with stetches of sand and grit fouled with mud covering the rocky bottom in most of the places. The fauna is similar to that of the previous area. But the starfish population is considerable, *Protoreaster australis* (Lutken) being very common. Simple and compound ascidians, and gorgonid sespecially *Juncella* sp. are also seen here and there. Another rocky stretch lying at depths of 5 to 7 metres northeast of Rameswaram shows rocky bottom with live corals of *Acropora* sp., *Pocillopora* sp., *Echinopora* sp., *Montipora* sp., *Favia* sp., and *Porites* sp., growing in abundance with the crannies and crevices inhabited by small coral fishes. Gorgonids and ascidian colonies are commonly seen. This area is rugged and is fairly extensive being longer than broad. Another rocky stretch situated at 10–12 metres depth also shows similar features with fewer numbers of live coral blocks and more numbers of starfish and holothurians particularly *Holothuria scabra.* In this area a few numbers of *Pinctada chemnitzii* occur lying loose at the bottom.

Although the rocky nature of the bottom of the Rameswaram area is very much like that of the shoreward areas of the Gulf of Mannar, it also suffers from the drawback of permanent turbidity with lot of silt–laden water always overlying the bottom. Rameswaram area has the advantage of a hard rocky core underneath unlike the Tondi area. But the present set up does not seem to be quite suitable for pearl oyster settlement. The mud deposit on the paar is unavoidable since the adjacent areas beyond 12 metres in Palk Bay is predominantly sandy and muddy which causes a perennial turbidity over the rocky zone due to swells affecting the bottom throwing up silt in suspension and consequently enveloping the low rocky relief. This feature is not the case with the oyster beds in the Gulf of Mannar and therefore the chances of the oyster spat settling down over the paar area in the Gulf zone appear to be more than in the Bay zone.

ECOLOGY OF CHANK BEDS

A. Gulf of Mannar zone

The habitat of the chank, *Xancus pyrum* was considered to be comparatively shallow water region and the minimum depth at which it was taken was stated to be 11 fathoms (Moses, 1923). But the observations of the authors (1968) using SCUBA have shown that chanks of large size are available at 25 metres depth also in sufficiently large numbers as to warrant commercial exploitation with the help of aqua-lung diving. Beyond this limit also chanks might

exist but it remains to be explored in due course. The shoreward limit of chank population cannot be exactly delineated as instances of chanks being taken from even less than 6 metres have come to our notice. This depth can be considered as the minimum depth for chanks to exist in fair quantities. It would be therefore reasonable to assume the ideal depth range for the chanks to flourish is between 10-27 metres.

Hornell (1922a) has shown ten chank beds between the region from Manapad to Vaipar in the Gulf of Mannar without mentioning how he demarcated these beds. Till 1968 there was no other record to show exactly the disposition of the chank beds and their extent. But a survey of the sandy bottom between Pinnakayal and Vaipar undertaken by the authors using SCUBA in 1962 to find out the nature of the sea floor, faunistic richness and the density of population of chanks in different depths enabled the plotting of chank grounds accurately. The chart prepared thus (Mahadevan and Nayar, 1968) brought to light extensive beds between long. 78°20′ E–78°35′ E (Fig. 15). The region between Pinnakayal and Manapad (8°25′ N Lat–8°35′N Lat.) remains to be investigated after which it is proposed to explore the regions north of 8°55′ N latitude. It is proposed to give a comprehensive picture of the chanks beds in Gulf of Mannar and Palk Bay at the end of the investigations.

From the studies on the nature of bottom in the regions investigated so far it is evident that the sandy sea bottom in which chanks are found can be divided into the following five categories:

a) Coarse sand region with plenty of worn out, drifted, brown coloured, broken shells of the species of *Arca, Anomia, Cardium, Crucibulum, Bulla, Meretrix, Nassa* and *Dentalium* along with small molluscs, echinoid spines, quartz grains and a few foraminiferan shells. This area extends from 8 metres upto 13 metres limit.

b) A region with sand grains of brownish colour in between coarse and fine grade, inhabited here and there by *Clypeaster humilis, Salmacis bicolor, Holothuria atra* and *Murex tribulus*. The percentage of broken shells was less while that of foraminiferan shells was higher than in the previous region. The area extends from 13 to 17 metres.

c) A region of fine sand of silky texture, superficially muddy coloured with loosely lying small corals, dense growth of *Solenocaulon* sp., *Pteroides* sp., *Virgularia* sp., tests of *Echinolampus* sp., *Clypeaster humilis*, occasional *Astropecten* sp., *Rhabdocynthia* sp. and sea anemones like *Stoichactis giganteum*. Broken shells were rare while foraminiferan shells were fairly common. The area extends between 18 and 23 metres. The sandy bottom appeared furrowed.

d) A region of very fine, loose sand in furrowed formation with *Rhabdocynthia* sp., alcyonarians, pennatulids, a few *Holothuria atra*, filamentous green algae etc. This region extends from 23 to 27 metres. The floral population here often consisted of *Avrainvillea* sp., *Halophila ovalis* and *Cymodocea* sp.

e) A region of sand, spread along the periphery of the rocky areas. This showed a mixture of all conditions seen in (b), (c) and (d). Here the sand was spread 10–25 cm over the hard bottom. *Porolithon* sp., dead coral pieces, scattered calcareous sea-weed *Halimeda* sp., algae belonging mostly to Rhodophyceae group grew here and there and dead shells were seen in addition.

It is mostly in the last three types of environment that the chanks were found in large numbers. A few were found at random in region (b) while in (a) they were very rare. The calcium content of the bottom zone especially in areas (c), (d) and (e) ranged from 10,490–12,930 mgm/l, a value considered high, when compared to other regions in the Gulf of Mannar (Malu Pillai, 1962). The temperature over these areas ranged from 26°C to 30·5°C (May), and pH 8·1 (May) to 8·6 (August). The salinity ranged from 32·07‰ (Nov.) to 35·91‰ (September) and the dissolved oxygen varied from 6·84 cc/l to 3·4 cc/l.

'Drift method' diving observations made over these areas have consistently confirmed that it is mostly in the last three types of habitat that the chank population was dense. During the trimester, January to March chank egg capsules were found planted in large numbers only in these types of environment whereas in areas (a) and (b) the picture was rather thin and bleak.

Judging from the various factors above it appeared reasonable to conclude that environments (c), (d) and (e) constitute the chank grounds where a great proportion of available food material as well as the calcium content in the surrounding water would help in providing the ideal habitat for the chanks.

B. Palk Bay zone

In the Palk Bay area, however, a different variety of chanks with shorter spire thrive well in less deep water at depth range 12–14 m. The nature of bottom is essentially of sand of fine texture superficially muddy, inhabited by *Pteroides* spp., *Virgularia* spp., *Salmacis* spp., *Clypeaster humilis*, *Holothuria scabra*, *H. atra*, *Astropecten indicus*, *Pentaceraster australis*, *P. affinis* and *Solenocaulon* spp. The polychaete fauna appears to be richer than in the area of corresponding depth in the Gulf of Mannar as evidenced by innumerable numbers of tube-dwelling polychaetes, especially terebellids found over the bottom. Many hundreds of square metres are populated by such a combination of *Xancus*-terebellid-echinoderm communities. Thus the habitat in Palk Bay zone also appears an ideal one for the chank to thrive well.

In the Gulf of Kutch area and west coast grounds along Kerala not much information is available about the ecological conditions of the chank beds.

The chank is an excellent instance of the acquisition by an animal of characters which appear for all practical purposes absolutely perfect to enable to hold its own with ease in the struggle for existence. Against every one of its known enemies it appears to have suitable means of defence. Several large pits are commonly seen in the grounds created by the smaller and larger rays and skates resting on the bottom. Naturally the chanks are exposed to the attacks of these predators. But the thick and massive shell of the chank and the animal's semi-burrowing habits given it protection against rays and other fishes which have the habit of either snapping the protruded feet of this gastropod or wrench-the shell. The thick periostracum protects it to a great extent from the insiduous attack of the boring sponge, *Cliona* sp. and its shell-boring congenors. The strong capsule it constructs for its young gives them adequate protection till they reach a self-supporting stage endowed even at this early period with a resistant shell. The camouflaging colouration of the periostracum with that of the bottom on which the chank lives affords further protection against its presence being discovered by enemies.

The outline of the various important rocky outcrops in the area between Vaipar and Pinnakayal studied and chartered by us (Mahadevan and Nagappan Nayar, 1968) shows a changed pattern when compared with the figures given by Hornell (1922a). This difference might be due to the gradual silting up of the rocky areas since Hornell first outlined them or it may be that his marking of the contours of the paars was approximate, not entirely based on scientific method of surveying them, the latter being more probable since nowhere had he stated how he drew the outlines of the paars. It is possible that they were based on the detailed information he obtained from the local fishermen and from the bearings taken from the log books of the motor launches engaged in pearl bank inspection work. The same is true of the position and extent of the chank beds which he had shown in the same maps. The survey conducted by the authors had helped to demarcate the exact position and extent of not only the paar area but also those of the chank grounds as well, although it should be admitted that much work remains to be carried out in the area south of Pinnakayal upto Manapad and in the sector north of Vaipar also.

Regarding the physical characteristics of the paars in Palk Bay and Gulf of Mannar it is noted that the sea bottom in Palk Bay is unsuitable for the settlement and growth of the pearl oyster *P. fucata*. The Rameswaram area, however, shows rocky bottom but for reasons which are beyond our control no pearl oysters ever settle down here. During the period 1950–1960 when myriads of oysters had settled down and supported successive fisheries off Tuticorin area in the Gulf of Mannar, the Rameswaram beds remained thoroughly barren through-

out. Perhaps the current system in the area does not carry the veligers to the eastern side of the Rameswaram Island and even if it does the larvae drift too far away and perish.

Added to this is the permanent turbidity of the watermass over the bottom due to muddy sediment suspension in Palk Bay. As such the usefulness of Rameswaram beds for pearl oyster settlement is rather questionable. This is supported by the fact that from the records of inspection done in that area for over 70 years not a single instance is there to show that pearl oysters had settled down in that area. However, it is noticed that *P. chemnitzii* which is not considered good as a pearl bearing oyster exists in considerable numbers in Palk Bay lying loose over the sandy and muddy bottom, a feature constrasting with the Gulf of Mannar.

The chank beds in Gulf of Mannar and Palk Bay are equally important and are very productive. In recent years there has been a spurt in the landings from Palk Bay side due mainly to greater number of divers operating there. In the Gulf of Mannar the fishery is not brisk. This is more due to administrative difficulties rather than due to paucity of chanks in the beds. Survey of the beds off Tiruchendur would help to bring to light possibilities of further expansion of chank fishing Industry and it is hoped to study these beds in the near future.

VIII CHANK FISHERIES AND INDUSTRIAL USES OF CHANKS

K. Nagappan Nayar and S. Mahadevan

The fishery for the chank in the southest coast of India has been the regular calling of the fishermen of the region from time immemorial. A look at the statistics of chank landings for the recent years from the important areas of fishing will show (Tables XV to XX) the large quantities of chank fished annually. But for a negligible percentage of these, the entire stock goes to Bengal where there is an organised small-scale industry for chank bangles. About 12,000–13,000 artisans in West Bengal are engaged in this profession. The present level of supply is found to be far below their requirements since the chanks which otherwise they can get from the Ceylon coast are not available now as in the pre-independance days. This is because of the fact that in those days the Ceylon fishery was conducted with the help of divers drawn from India. Now these divers are not allowed to go there as a result of which the fishery in Ceylon has suffered a great set-back. This has considerably helped the chank fishing in India to prosper.

It is felt that if a proper survey of the chank resources of our waters is undertaken and if the tempo of the expolitation is increased, there is every possibility of the chank industry expanding further. This will give greater profits to the fishermen and the people who are engaged in the chank bangle industry and greater revenue to the Governments of the states where chank fisheries exist. The following account is presented with the object of drawing the attention of scientists to the existing chank fisheries of India and to indicate the possiblities for expansion of the fisheries based on (a) the results of a preliminary survey conducted to find out the extent of chank beds notably in the Gulf of Mannar and (b) on the effectiveness of modern methods of exploitation.

Distribution of chank, areas of occurrence and depth

The chank is extremely abundant on the east coast of India being found and fished everywhere from Cape Comorin to Madras (Fig. 15–18) although the density of its occurrence appears to thin out north of Point Calimere. The northern limit of this coast may be put as the mouth of the Godavari. On the west coast its geographical distribution is peculiar. Large numbers are fished in the

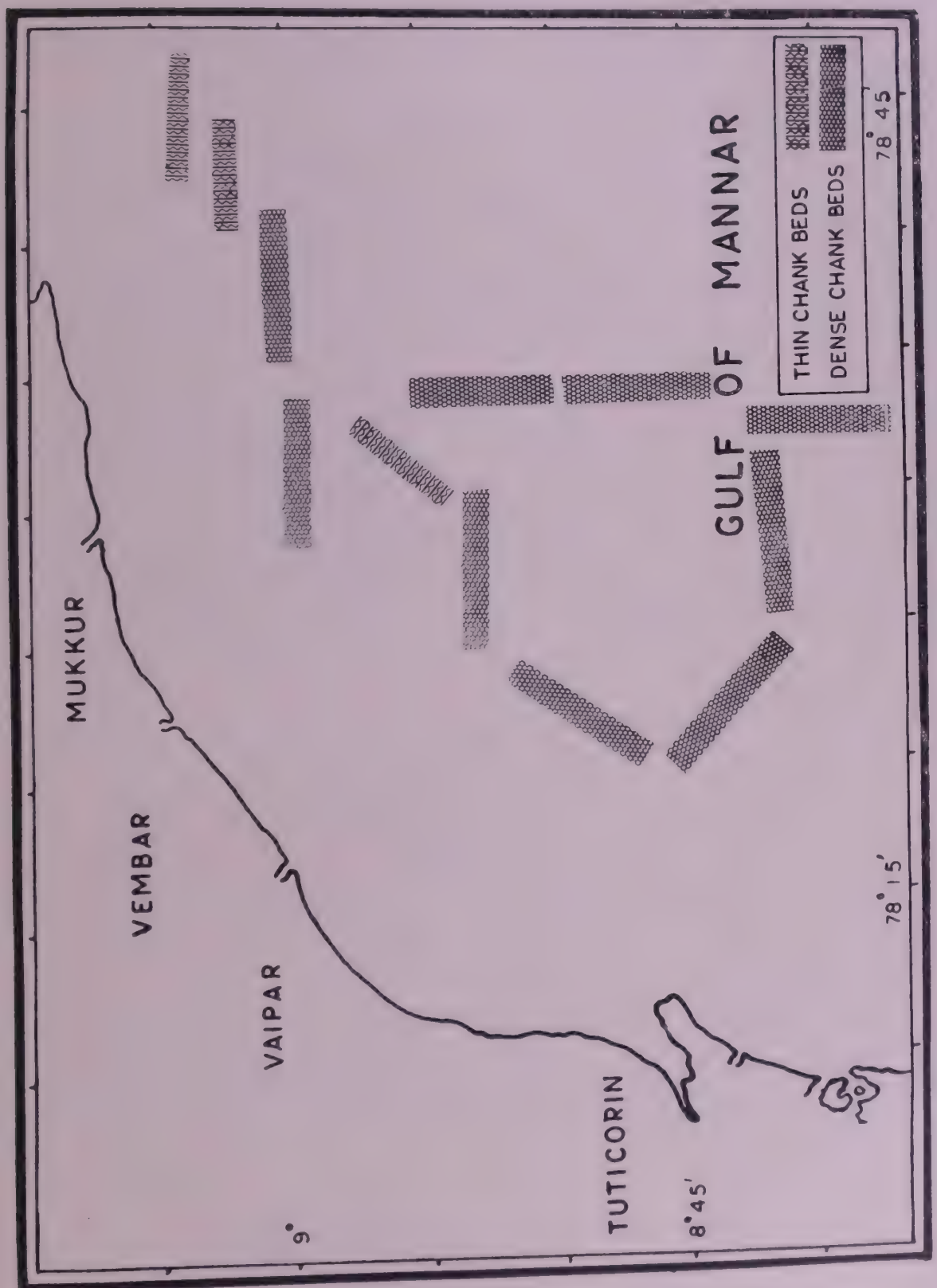

Fig. 15. Diagramatic representation of the disposition of the chank beds in the zone between Tuticorin and Kilakarai in the Gulf of Mannar.

Gulf of Kutch coast, but southward of this no trace of the chank is found up to southern coastline of the Kerala State where this shell appears and forms a small fishery (Fig. 18). It is also found in the Andaman Island.

Being gregarious, its haunts form distinct beds. The most important beds are in the Gulf of Mannar along the Indian coast in depths 10–20 metres with sandy bottom (Hornell, 1922b). In the Palk Bay to the north of Adam's Bridge it occurs at lesser depths up to 12 metres in sand mixed with mud. Along the Coromandal coast it is found on sand mixed with mud at depths varying from 6–20 metres. The chanks fished off Trivandrum and Kanyakumari districts coast are also found in the depth range 10-20 metres. Along the Gujarat coast the chank is found on or about the coral reefs where one can wade through the shallow water to pick the chanks (Gokhale, 1963). The depth of occurrence on the Ceylon coast is very much the same as that of Palk Bay and Gulf of Mannar coasts of India. In the shallow waters off the land-locked Jaffna lagoon chank is found as sub-fossil deposits where people wade through and collect. Generally speaking the chank beds may be defined as those which have fine sand of silky texture, superficially muddy coloured with loosely lying small corals and other paar detritus adjacent to the margins of the rocky sea beds or a region of very fine loose sand in furrowed formation with a crust of filamentous green algae (Mahadevan and Nagappan Nayar, 1966). In addition to the above, chank is found on reefs or on sea floor covered with an ad mixture of sand and a little mud or on gravel and coarse sand.

Chank fisheries of India

The following are the distinct chank fisheries that exist today.

1. Madras coast :
   a. Tirunelveli fishery
   b. Ramanathapuram fishery
   c. Sivaganga fishery
   d. Tanjavur fishery
   e. South Arcot and Chingleput fishery
   f. Kanyakumari fishery
2. Kerala coast :
   a. Trivandrum fishery
3. Gujarat coast :
   a. Gulf of Kutch fishery

Without exception the fishery in each state is Government monopoly although the *modus operandi* in the expolitation of the chanks varies from place to place.

Tirunelveli Fishery :

The fishery along the coast of Tirunelveli from Kootapuli to Kannirajapuram, a distance of about 136 km with Tuticorin as the headquarters,

TABLE XV

Chanks fished from Tuticorin in the years 1931–32 to 1966–67

Years		Fullsize	Under-sized	Wormed
1931–32	...	309943	62711	17016
1932–33	...	309226	79971	27438
1933–34	...	441520	79010	26067
1934–35	...	326999	68892	13187
1935–36	...	323475	145081	20781
1936–37	...	398782	58526	6364
1937–38	...	309257	37187	13256
1938–39	...	363960	36578	6547
1939–40	...	539662	58224	7987
1940–41	...	436626	47882	13509
1941–42	...	495403	46113	20377
1942–43	...	458894	29918	46421
1943–44	...	430274	29541	24500
1944–45	...	268318	21033	13664
1945–46	...	476302	19622	13596
1946–47	...	666	475	120
1947–48	...	683919	25859	27021
1948–49	...	599103	397183	28368
1949–50	...	1034667	56826	30225
1950–51	...	983815	63345	30831
1951–52	...	681006	42025	19189
1952–53	...	944666	64380	50843
1953–54	...	900345	83997	61438
1954–55	...	346680	28305	9987
1955–56	...	503365	32338	16838
1956–57	...	660869	35045	27387
1957–58	...	860472	30858	30470
1958–59	...	1155644	61871	43357
1959–60	...	1134191	47946	64857
1960–61	...	561726	76388	28446
1961–62	...	574893	82311	33059
1962–63	...	459762	115792	43658
1963–64	...	355439	71639	28711
1964–65	...	112046	39877	17088
1965–66	...	7031	4546	1856
1966–67	...	265344	50984	18304

is controlled by the Tamil Nadu Government and the exploitation is done departmentally. The important centres where chanks are collected are Idinthakarai, Ovari, Tiruchendur, Kayalpattinam and Tuticorin.

The fishing season starts from the middle of November i.e. the beginning of north-east monsoon period and lasts till the end of May when the south–west moonsoon sets in. This is one of the very important fisheries yielding annually about 5,00,000 of good chanks valued at Rs. 8,00,000 annually.

RAMANATHAPURAM FISHERY :

The ex-Ramanathapuram zamindari fishery along the Ramanathapuram district coast from Kannirajapuram in the Gulf of Mannar to Pamban and from Rameswaram to Karagadu in the Palk Bay, an approximate distance of 190 ½km

TABLE XVI

Chanks fished from Ramanthapuram and Sivaganga waters in the years 1954–55 to 1966–67

Years	Full size	Under-sized	Wormed	
1954–55	325505	21819	26678	Ramanathapuram
	3824	374	330	Sivaganga
1955–56	349609	16853	7185	Ramanathapuram
	6544	780	1569	Sivaganga
1956–57	392573	23747	23612	Ramanathapuram
	124572	3478	28141	Sivaganga
1957–58	690510	21287	48413	Ramanathapuram
	243153	1680	60256	Sivaganga
1958-59	533085	14741	50394	Ramanathapuram
	66831	22029	—	Sivaganga
1959–60	587960	52815	8923	
1960–61	1059099	64931	16893	
1961–62	688668	56355	2038	
1962–63	822622	72283	21341	
1963–64	895624	98615	15765	
1964–65	252168	36390	9382	
1965–66	844401	73090	17148	
1966–67	6223	4683	27693	

Separate figures of chank fisheries for Ramanathapuram and Sivaganga waters are not available from 1970.

is leased out to a private party. The important centres in the region from where fishermen go out for chank fishing during the season and the season of fishing are as follows :

	Place	Season
Gulf of Mannar :	1. Kannirajapuram	Dccember to March
	2. Kilakarai	September to December
	3. Periapatnam	September to December
	4. Vedalai	September to December
Palk Bay :	5. Rameswaram	March to June
	6. Thangachimadam	March to June
	7. Pamban	March to June
	8. Devipatnam	June to Semptember
	9. Irumeni	May to August
	10. Tiruppalakudi	June to September

Annually about 3,00,000 of chanks are fished from this area and the rental derived amounts to nearly Rs. 2,25,000.

CHANK FISHING OF OTHER REGIONS :

The ex-Sivaganga zamindari fishery from Karangadu to Sundarapandyan-pattinam, a distance of about 30 km is separately leased to a private party although this area is also part of the Ramanathapuram district. The important fishing centres are Karangadu, Mullimunai, Tondi, Pasipattanam, and Vattanam. The season of fishing in this area is from April to October.

The number of chanks fished in this area being very small, the amount realised out of leasing the fishery comes roughly to Rs. 30,000 per year. All along the coast of Thanjavur district except for a short distance between Point Calimere to Pudukuda, the right of collection of chanks is leased to private party. There are about 20 centres of collection of chanks of which Mullipattinam, Chinnamunai, Senthalai, Periathambiranpattinam, Gopalapattinam, Adiram-pattinam and Sethubavachatram are important. Only about 30,000 chanks are fished annually and hence this is a minor fishery only. There is no particular period in which the chanks are fished. Fishing may be said to extend all through the year since no diving work is involved.

The fisheries of South Arcot and Chingleput districts are of very minor importance. Annually less than 15,000 chanks are fished. The fishery is leased out for an amount of about Rs. 17,000 per annum. Chank is fished as and when they are available along the coast. The fishery extending from Cape Comorin to Thuttur, a distance of about 65 km is also leased out to private party The important centres of collection are Muttam, Colachel, Thenga-pattinam, Enayaputhanthurai, Kodimunai and Ramanathanthurai.

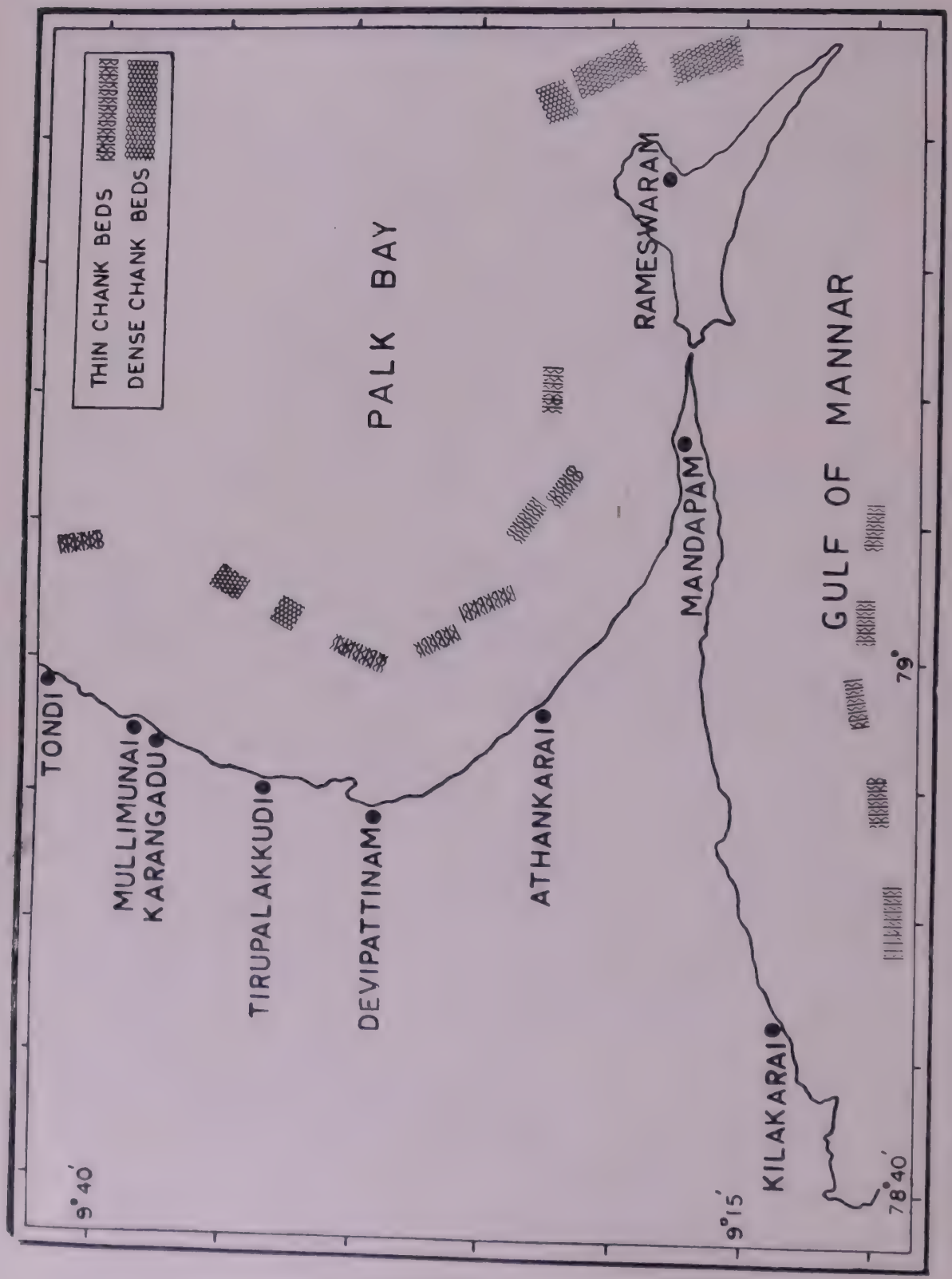

Fig. 16. Diagrammatic representation of the disposition of the chank beds in zone between Kilakarai and Rameswaram in the Gulf of Mannar and the zone between Rameswaram and Tondi in the Palk Bay.

TABLE XVII

Chanks fished from the Thanjavur district in the years 1952–53 to 1966–67

Years	Full size	Under-sized	Wormed
1952–53	33239	5891	8816
1953–54	43007	163	13990
1954–55	11832	4677	657
1955–56	17992	7068	766
1956–57	31768	13099	1566
1957–58	41394	6459	815
1958–59	44981	10644	5257
1959–60	30299	7142	1217
1960–61	33239	5891	8816
1961–62	43007	163	13790
1962–63	43945	23731	10999
1963–64	33237	18297	10999
1964–65	43391	17855	12405
1965–66	29452	14768	540
1966–67	13816	7505	5897

TABLE XVIII

Chanks fished in the Kanyakumari district in the years 1957–58 to 1963–64

Years	Full size	Under-sized	Wormed
1957–58	2032	282	361
1958–59	2702	922	280
1959–60	2485	239	735
1960–61	8607	2909	244
1961–62	13231	1409	4
1962–63	10103	1994	1385
1963–64	5945	4556	–

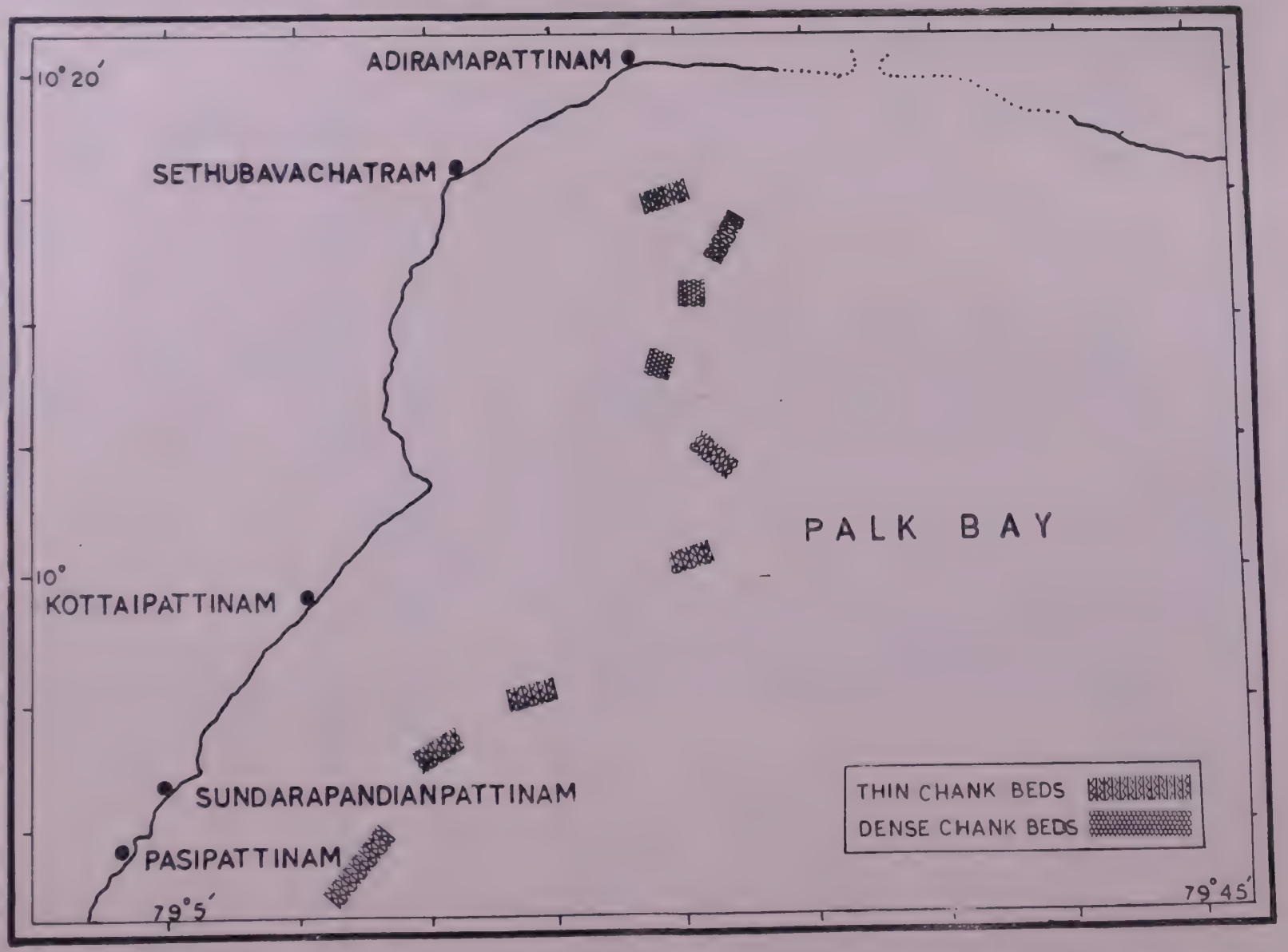

Fig. 17. Diagrammatic representation of the dlsposition of the chank beds in the Palk Bay Zone between Tondi and Sethubavachatram.

The season of fishing extends from middle of January to the end of April. About 10,000 chanks are fished annually and the lease amount comes to approximately Rs. 5,000 per year. The Trivandrum fishery is leased out by the Government to Co-operative Societies on a minimum royalty basis. The amount realised is about Rs. 20,000 per year. The important places where the chank is collected

TABLE XIX

Chanks fished from Kerala State : Trivandrum fishery from 1956–57 to 1962–63

Years	Numbers of chanks fished
1956–57	16125
1957–58	18355
1958–59	26629
1959–60	23979
1960–61	23975
1961–62	21294
1962–63	10443

are Poovar. Vizhinjam, Kovalam, Cheriathurai, Valiathurai, Sankumugam, Veli and Cherumankarai along a stretch of nearly 60 km. The fishing season is from December to April.

GULF OF KUTCH FISHERY :

The Government of Gujarat does not engage any fishermen for the collection of the chank. But the local *wagher* fisherfolk collect and surrender them to Government in different places. The intertidal zones of Okha, Aramda, Poshitra, Ajad, Wadinar, Bharana, Salaya, Sikka, Pirotan Island and Bedi on the southern side of the Gulf are the important places located approximately over a distance of 130 km.

METHODS OF FISHING FOR THE CHANK IN VARIOUS LOCALITIES

In the Gulf of Kutch the local fishermen make the collections by picking the chanks from the intertidal flats. Along the Triuvandrum and Kanyakumari coasts they dive for the chank. Similarly on Tirunelveli, Ramanathapuram and Sivaganga coasts also the fishermen do skin diving and bring the catches and sell them either to the Government or to the lessees as the case may be. In the Coromandal coast the Thanjavur fishery is mainly dependent on the shells obtained fortuitously in the course of net fishing by catamaran fishermen. The bulk of the shells are taken by *vellai valai*,

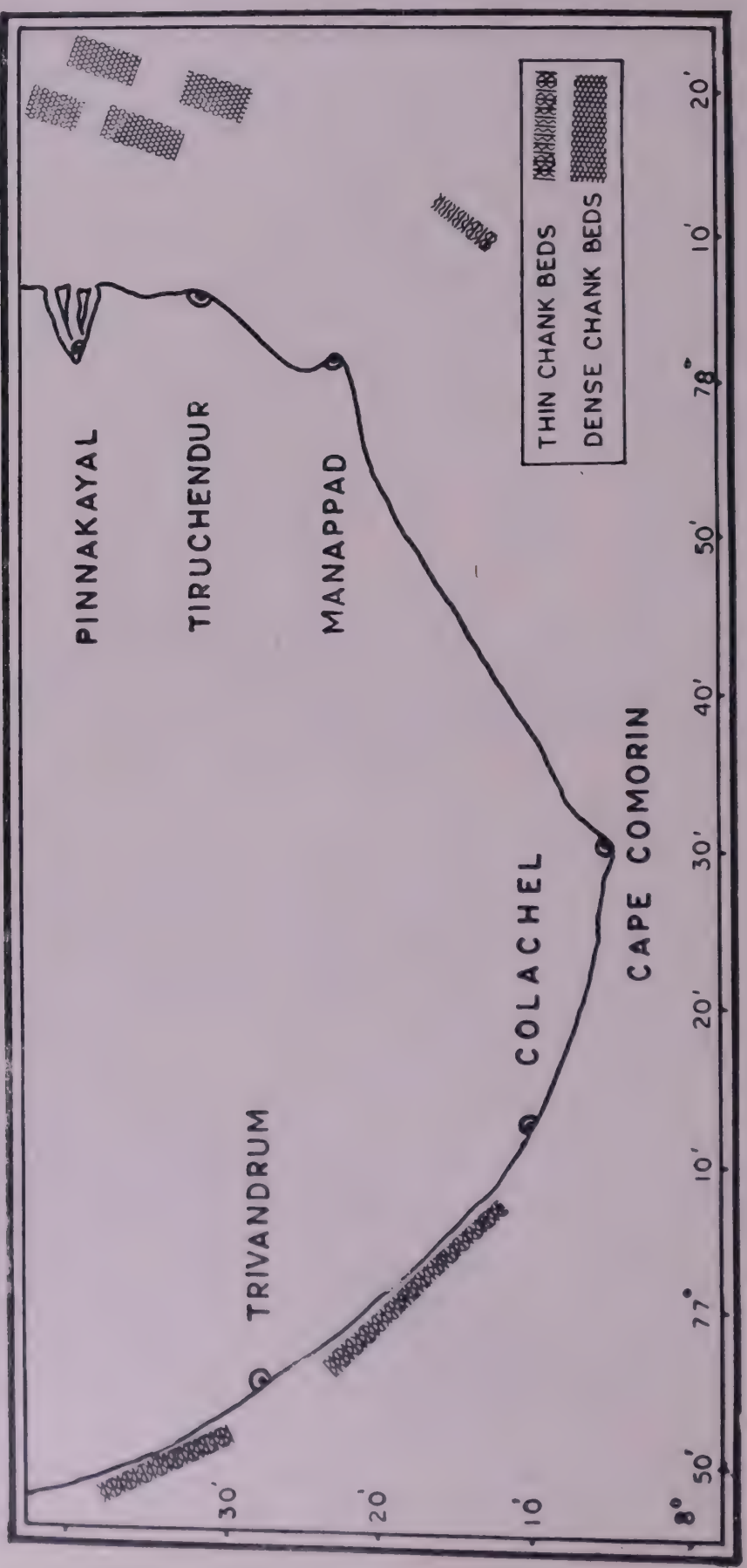

Fig. 18. Diagrammatic representation of the disposition of the chank beds in the zone between Tuticorin and Cape Comorin in the Gulf of Mannar and in the zone between Cape Comorin and Trivandrum in the west coast.

a light trawl operated by two catamarans. Along the South Arcot coast chanks are taken in *thurivalai*, which is also a catamaran light trawl.

TABLE XX

Chanks fished in Gujarat State in the years 1952–53 to 1966–67

Years	Numbers of chanks fished
1952–53	14058
1953–54	16752
1954–55	14419
1955–56	11628
1956–57	10002
1957–58	10601
1958–59	15580
1959–60	23037
1960–61	16079
1961–62	19373
1962–63	18123
1963–64	25655
1964–65	24752
1965–66	13688
1966–67	12161

In the Ceylon coast also chanks are dived for and taken by skin divers as in the case of Tirunelveli coast, modified in many places by the fact that the beds are in shallow waters so that the divers dispense with the stone and the rope. In the shallow Jaffna lagoon, approximately an area of 670 sq. km. the fishermen wade through shallow water up to 1·5 metres depth and with the help of a long iron rod search in the mud till they strike against a chank. They hook it with other end of the iron rod where they have provided a hook and bring the chank to the surface. This method requires great dexterity.

It may thus be seen that the most important method of chank fishing is by skin diving although it is an age-old method. The best skin diver will be able to keep himself under water for a little over a minute and he can make about 40 dives a day, depending on his ability and the weather. Although the craft used in carrying the divers differs from place to place in shape, size and capacity, the Tuticorin type of boats are the most common and they can carry about 10–15

persons while the Kilakarai type of boats and Tondi type of boats which are heavier and balanced with planks and outriggers respectively can carry more number of divers. Mechanised boats are not used at present in commercial chank fishing anywhere in India. It has been estimated that there are about 1,000 divers drawn from Tirunelveli, Ramanathapuram and Kanyakumari districts only taking part in the chank fisheries of the Gulf of Mannar and Palk Bay.

Varieties of chanks fished commercially

Hornell (1915) distinguished 5 well marked sub-species of the central form *Xancus pyrum* (Linn.) in different localities. The diversities are attributed to the differences in the nature of environment, such as exposure to unfavourable conditions like surf action, prolonged spells of turbid mud-laden water, and physico-chemical properties of the water in which they live. The differences in the varieties depend mainly on the ratio of length and width, the ratio of the axial length to the diameter of the body whorl, weight of the shell and the thickness of the periostracum. The varieties distinguished are 1. *Xancus pyrum* var. *obtusa*, 2. var. *acuta*, 3. var. *globosa*, 4. var. *comorinensis*, and 5. var. *fusus*.

The barrier formed by Rameswaram and Mannar Island and Adam's Bridge very nearly forms a dividing line; *obtusa* being found entirely north of this line while *acuta* is found in the coastal waters of the Gulf of Mannar. But in and around Rameswaram up to Mandapam a small number of chanks locally called *Irupiravi* meaning 'two origins' are found showing characters of *obtusa* in the matter of formation of spires and the appearance of opercular region like that of *acuta*. The varieties of *globosa* and *comorinensis* are viewed as closely related forms of *acuta* and are restricted to the extreme south of Indian peninsula running northward from Cape Comorin on the east and west coasts for nearly 20 km and 64 km respectively. *Comorinensis* lives in shallow water exposed to heavy swells. The variety *globosa* lives at greater depth in the same geographical range. The variety *fusus* is confined to Andamans and has developed fixed character because of its isolation. The Gulf of Kutch form appears almost identical with the Rameswaram variety perhaps due to identical habitat in which they live.

The variety *acuta* is called 'Jadhi' (Pl. III A) and *obtusa* is known as 'Patti' in commercial parlance. Even amongst these two there appear to be many local races, although difficult to distinguish clearly as such.

A. Variety *obtusa*:

Judging the importance in both Indian and Ceylon catches, from the numerical point of view, this variety occupies the first place, making up all except a fraction of the produce of the great fisheries in the north of Ceylon and along the Indian coast of Palk Bay and from Point Calimere to Madras. The characters

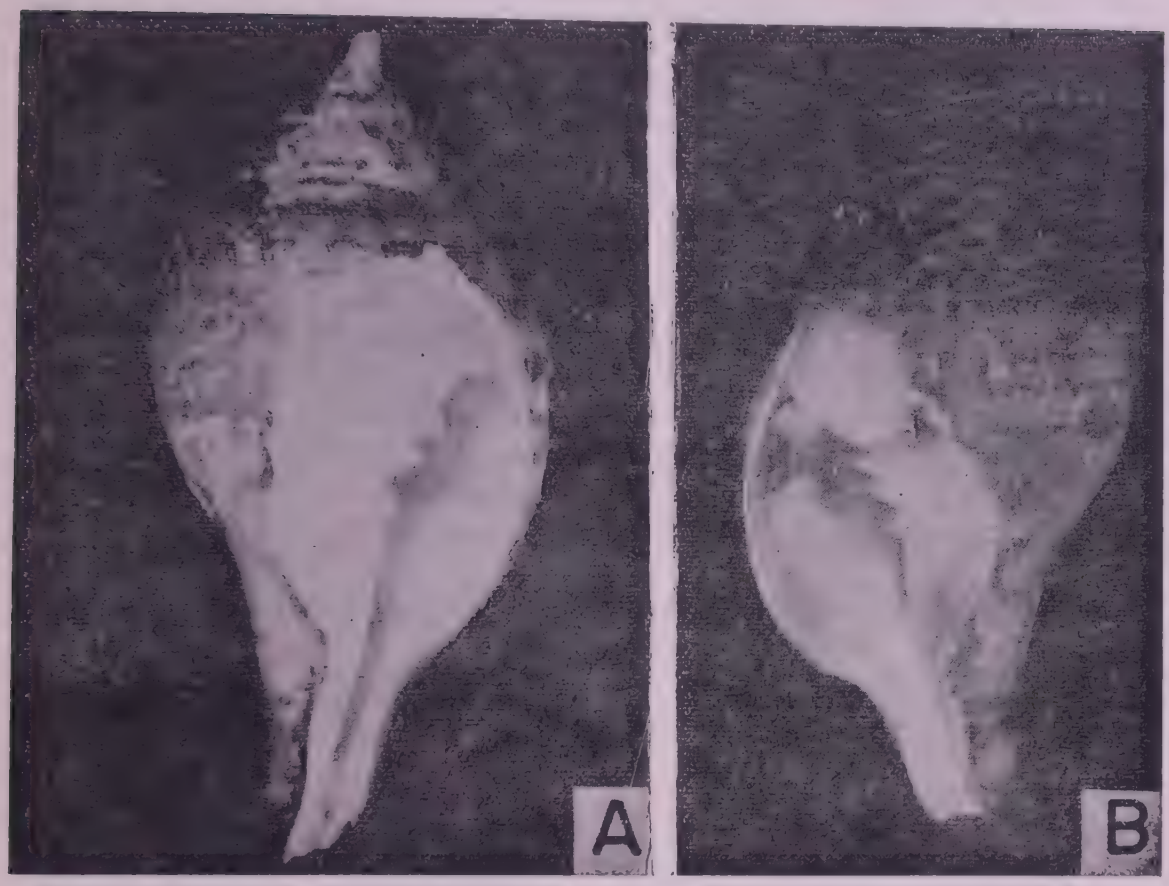

Plate III. A. *Xancus pyrum* var. *acuta* (Jadhi). B. *X. pyrum* var. *acuta* (Sinistral type called Valampuri).

of this variety fluctuate within considerable limits, from a form with well-marked though short spire (Irumeni, Devipatnam race) to one in which it is extremely abbreviated with whorls much telescoped (Tiruppalakudi race).

B. Variety *acuta*:

Next in importance to variety *obtusa* comes this elegant form, comparatively narrow, moderately elongate with well-balanced spire. The breadth in length averages to 1·83 and is lower 1·75 in short specimens. Apart from the variety represented in Gulf of Kutch three well-marked local races are present at (1) Tuticorin, (2) Kilakarai and (3) Rameswaram.

On account of the local varieties having different physical characters, their usefulness in the bangle industry also varies with the result that the price offered also differs. The shells from different localities are kept and sold separately. The

Tuticorin and Kilakarai forms are considered best amongst 'Jadhi'. 'Jaffna' and Ceylon chanks come close in esteem. The chank bangle manufacturers distinguish the following qualities:

1. Tuttikudi	2. Ramessari	3. Patti
4. Jammaipatti	5. Noyakhad Patti	6. Gharbaki
7. Duani and	8. Surti	

The 'Tuttikudi' chanks are well-known for their opalescent whiteness, greater hardness and evenness of texture. 'Ramessari' approaches quality (1) but are slightly inferior. These are shells fished off Kilakarai and Rameswaram. 'Patti' shells fished in the Palk Bay of which 'Jammaipatti', the shells fished off the mainland to the north of Mandapam and from there to Tondi, are held inferior to 'Jadhi'. The 'Noyakhad patti' are north of Mannar Island. The quality 'Gharbaki' is a class of squat shells badly adapted for cutting. This comes from the Coromandal coast from Point Calimere to Madras with colour and shape defective and the shell is more brittle. 'Duani' fished off Travancore is a large, excellent variety used as bracelets. 'Surti' from Kutch area is esteemed high as 'Ramessari'. It may be thus seen that the shells of Kutch, Gulf of Mannar and Rameswaram are in great demand as first quality shells while the rest come next in importance.

Fishery Value

Of late there is a good demand for the chank flesh as an item of food by many sections of people. The chank flesh is rich in protein and minerals (Chari, 1966) and the values compare favourably with fishes. It is the foot of the animal which is scooped out of the shells by means of a sharp curved knife. The flesh so scooped out is boiled and sun-dried after which chips are made. It has been observed that from 100 chanks two litres of flesh are taken, the cost of which ranges from Rs. 4/- to Rs. 5/-. Thus if the annual landings of chanks is one million shells the fishermen derive Rs. 50,000 by the sale of the flesh alone. In addition to the above there is a great demand for the chank operculum from merchants in Mysore State for making incense sticks. One kg of operculum costs Rs. 50/-. It has been estimated that 10,000 chanks yield this quanitity. Therefore, out of one million shells the fishermen derive an additional income of Rs. 5,000.

The prices paid by the private and public sectors for the chanks are different in different areas. For instance, in the Gulf of Kutch chanks above 90 mm diameter are paid Re. 0-90 each and a chank between 60 and 90 mm diameter at Re. 0·60. The disposal rate is rather very high being Rs. 7/- and Rs. 6/- respectively. The Ramanathapuram chank is paid a price ranging from Re. 0-40 each (Devipatnam) to Re. 0–65 each (Kilakarai). The Government of

Tamil Nadu pay Re. 0-60 per chank for shells from Tirunelveli coast. Taking on an average that the rate of a full sized chank is Re. 0-60, the revenue of the fishermen would amount to Rs. 6,00,000 for every million chanks fished. Mention may be made here of the additional revenue of the divers when a freak chank of *Valampuri* (Pl. III B) is fished by them. This sinistral form which is a freak is in demand as it is valued very much by Hindus and is used in worship in Hindu temples. The price offered for acquiring the *Valampuri* chanks is fantastic, ranging from Rs. 500/- for a chank of less than 45 mm diameter to Rs. 10,000/ or even more for a perfect chank of 65 mm or greater diameter depending on the size and competitiveness in the auction bids

The *Valampuri* is said to occur mostly in and around Rameswaram waters. On the Tirunelveli coast official records show that only three chanks have been fished so far in recent times, one in 1920, another in 1957 and the last in 1970.

The Government pay the cost of 1,000 ordinary chanks to the diver who brings one *valampuri* chank. The lessees of Ramanathapuram waters are supposed to surrender one *valampuri* chank per year to the Government (as per lease agreement) or the cost of 1,000 ordinary chanks in lieu thereof; invariably they give the latter. The Government auction the *valampuri* chanks by calling for tenders on all-India basis.

Exploitation of chanks at the present level

Before independence nearly 4/5s of the total requirements of chanks in Bengal were met by Ceylon and the rest from Tirunelveli and Ramanathapuram fisheries. The consumption was estimated to be 25,00,000 per year (Hornell, 1914). Since the supply from Ceylon dwindled, the level of output from the Indian coast has risen up to 15,00,000 per year. This is hardly sufficient to meet the demands from the market. It is necessary to intensify the fishing for chanks which necessitates an evaluation of the available resources, establishing new areas of fishing and improving technique of fishing.

India has a coast-line of 4,667 km. Of this chank is known to occur along a distance of 130 km in the Gulf of Kutch, 65 km in Kerala and 430 km in Madras coast (excluding 290 km of Thanjavur, South Arcot and Chingleput coasts). In the Gulf of Mannar and the west coast the chank living areas are known to extend nearly 16 km into the sea, whereas in Palk Bay it is 12 km and in the Coromandal coast it is 10 km. Thus it may be roughly estimated that 10,000 sq km of our inshore sea-bottom are potential chank grounds, leaving out Kutch area and the Andamans.

The present exploitation on all India basis suffers from many drawbacks. Many productive areas which are far off from the base of operations are rarely

tapped due to difficulties by way of towage to the sail-crafts employed. The divers rarely go out in search of new fishing grounds since it will be a waste of time and labour for them to spend their time in this. They are aware of only a few rich chank grounds which they exploit season after season. In areas like Gulf of Kutch, Thanjavur, Chingleput and South Arcot coasts diving for chanks is not done. In other areas where diving is done the method used is age-old and is dependent on fair weather, clarity of water and currents. There is also the limitation of depth to which a skin-diver can descend. If the fishermen are shown new areas of fishing, taught modern method of exploiting the chank and provided with motorised crafts it is bound to improve the fishery and the total output many fold. Towards this goal it was felt necessary and very useful to conduct underwater survey of the sea-bottom from 10-27 metres depth along our coast by direct observations using SCUBA * to find out:

1. the extent and exact location of the chank beds in various zones, and the density of populations,

2. new chank grounds in deeper waters so that these may also be exploited to increase the catches,

and 3. to demonstrate the usefulness of modern diving equipments in chank fishing.

Such a programme can be only a long range one and will take quite some-time to be completed. To start with, the survey of the sea-floor off Tuticorin was begun, since this is one of the important chank fishery zones. The results of this survey have brought to light extensive chank beds within Lat. 8°35′ N′-8°55′ N to to Long. 78°15′ E–78°35′ E (Mahadevan and Nagappan Nayar, 1968). The outstanding feature of the survey was the discovery of new chank beds. These beds lie within 20–25m and run north to south. The chanks were all large sized measuring over 60 mm in diameter which is an ideal size (A grade) for the bangle industry. In shoerward parts of this area, the density was much less and the size also smaller. This might be due to the fact that while many of the nearby beds are constantly fished the divers do not know the beds in the deeper water and they are unable to dive with their primitive method thus leaving a good population of chanks unfished. The fishermen rarely go to the southern beds off Tuticorin due to lack of proper facilities. Once a year they move over to Trichendur and exploit the beds close to the shore for a week or so and return to Tuticorin with their 6 days catches There appears to be insufficient effort and steps appear to be necessary to arrange regular fishing of this area.

* Self-contained underwater breathing apparatus.

INDUSTRIAL USES OF CHANKS

At the present day the use of chanks for industrial purposes is confined to the chank bangle industry only. Apart from this, chanks are of use in preparing lime for special needs and occasions as the lime made from the chank shell is found to be of superior quality. This is done in coastal districts and also in Bengal. But the shells are too valuable to be used for manufacture of lime. Native doctors in almost all the districts of Tamil Nadu prescribe chank powder in curing many skin ailments and in the treatment of eye diseases. But the chank bangle industry completely overshadows the other uses.

Two great centres of chank bangle manufacture existed in ancient times apart from the extreme south of Tamil Nadu, namely one in the southern Deccan and the other around the shores of the Gulf of Cambay. No chank cutting is done in any of these places now as the women in these parts have abandoned their habit of wearing chank bangles. Now chank cutting, save for some insignificant work done in Kilakarai near Ramanathapuram is a forgotten art with the exception of Bengal. The industry flourishes solely in West Bengal. mainly depending on shells supplied by Gujarat, Tamil Nadu and Kerala states. All the shells of the chank used in the bracelet-making industry are imported into Calcutta which is the sole emporium for chank shells. The women of Bengal wear bangles made from chank shells following a very old custom. The richly carved and highly polished chank bangles are traditionally worn by the women. The custom requires a bride to put on for marriage ceremony two red coloured chank bangles. Santals, Kochis, Tibetans and Maghs also wear roughly-carved bangles. In Asam, Tibet, Nepal and Bhutan also this custom is prevalent. Dacca was the chief centre for this industry before partition. But, after the independence of India the artisans in West Bengal have taken up this trade and numerous factories have been started, chief centres of the bangle industry being located in Calcutta, Bishnupur, Bankura, Jitpur (Murshidabad), Chandernagur and Midnapur. It is gathered that more than 13,000 artisans are engaged in the chank bangle industry. The West Bengal small-scale Industries Corporation purchases the chanks from Tamilnadu, Kerala and Gujarat and from reputed chank dealers like Messrs. A. M. S. Mohamed Aboobaker & Co., Messrs. Sultan & Co etc. at rates ranging from Rs. 2.50 to Rs. 9.00 per shell depending on the quality and size of the chanks.

The chanks are in turn sold to manufacturers of chank bangles at a slightly higher rate. At present the industry is not subsidised by the Government. The artisans known by different names are paid by the manufacturer at different rates, depending on the nature of their work. Cutting workers are paid at Rs. 12·00 per 100, polishing workers Rs. 4·50 per 100, finishing workers Rs. 32·00 per 100 etc. There are others like 'Ghasa' paid at Rs. 2·50 per 100, 'Majhar' at Rs. 12·00 per 100, 'Saj' at Rs. 3·00 per 100 and 'Bidhani' at Rs. 5·00 per 100.

It is estimated that it will be possible for one artisan to cut at least 75 pieces of chankbangles in a month. But the output by cutting machines which have been recently introduced seems to be nearly 300 pieces per month. While cutting the bangle is of little importance in the industry it is the designing, finishing etc. which need utmost care and attention. An ordinary artisan earns Rs. 4 per day as minimum wages while a skilled worker doing finishing work earns Rs. 10 per day. Detailed account of how chank bangles are sawn, polished, decorated etc. may be found in the writings of Hornell (1918) and the same practice is being followed even today.

The rate of disposal to the market of the finished product is rather profitable and some of the prevailing rates are as follows :

Bangles for Pooja purpose	...	Rs. 0·50 to 1·50 per pair
Bangles for ordinary use	...	Rs. 4·00 to 6·00 per pair
Bangles for use (fine finish)	...	Rs. 12·00 to 20·00 per pair
Chank rings	...	Rs. 0·50 to 2·00 per piece
Chanks for blowing purpose	...	Rs. 1·00 to 100·00 per piece
Chanks for Pooja	...	Rs. 0·50 to 50·00 per piece

The present state of the chank industry in Bengal is said to be dull because of the short supply of raw materials and due to high labour charges. Perhaps the industry can be revitalised by increased exploitation of chank resources and supplying the market with larger quantities of chanks.

IX OTHER COMMERCIAL MOLLUSCS

K. Satyanarayana Rao

In addition to the molluscan species dealt with in the preceding chapters, there are several others which are also of commercial value but have not so far received much attention from biologists in our country. In this chapter an account is given of what is known about the identity, habits, biology, distribution and utilization of these shell-fish.

WINDOW-PANE OYSTERS

The window-pane oysters occur in good abundance in a few places on the Indian coasts. They are so called because of their thin translucent flat valves with iridescent lustre which are utilized as window-panes. The window-pane oysters come under the family Anomiidae included in the order Anisomyaria. Members of the family Anomiidae have thin, flats shells, the inner surface of which have iridescent lustre and the body is asymmetrical. Two species of window-pane oysters are represented on Indian coasts, *Anomia achaeus* Gray and *Placenta placenta* Linnaeus *A. achaeus* is comparatively a rare species recorded from Madras harbour (Gravely, 1941) while *Placenta placenta* Linnaeus is a commercially important species. In *Anomia achaeus* the left valve is somewhat irregular and it completely covers the right, which is much thinner and closely adheres to the substratum. The right valve has a deep cleft in the young stage which closes in the adult, forming a perforation. Hornell (1909 a, b, c) has given a detailed account of the anatomy, distribution and utilization of *Placenta placenta.*

Placenta placenta (Linnaeus)

Synonyms

Anomia placenta Linnaeus 1758
Placenta orbicularis Retzius 1788
Placuna placenta Lamarck 1819
Placuna placenta Reeve 1873
Placuna placenta Hornell 1909 a
Placenta placenta Gravely 1941
Placenta placenta Satyamurthi 1956
Placenta placenta Rao 1969

COMMON NAME

English — *Window-pane oyster.*

DESCRIPTION

SHELL

The shell of adult oyster is free, very much compressed, slightly inequivalve, sub-orbicular in shape, the height and length approximately equal.

The shell valves are slightly unequal, very flat, rounded and translucent. The inner surface of the valves is pearly. The adductor impression is at about the centre. The umbo is small. Two thin ridge like teeth diverge from the umbo making a characterstic inverted V shaped angle. The shell is fairly large with a diameter of 14 cm or even more. It bears numerous concentric lines of growth on the exterior consisting of slightly projecting lamellae the margins of which are minutely uneven with finger-like or spatulate processes. The shell of the adult window-pane oyster is white in colour (Fig. 19 A).

BODY

The body is very much laterally compressed (Fig. 19 B) and is covered by two folds of mantle. Anteriorly on either side of the visceral mass is a pair of elongated, narrow labial palps between which is the mouth. There is a pair of gills (gl.) on either side of the visceral mass. The foot (f.) is cylindrical, flattened laterally and attached to the anterior surface of the visceral mass and its tip has a deep cup-like sucker which facilitates dispersal of foreign matter settling on the body. The alimentary canal consists of a slit-like mouth, oesophagus, a large stomach surrounded by the digestive gland, a well-developed pyloric caecum with crystalline style, a short intestine and a rectum which ends by anus in the centre of a broad everted membranous collar. The vascular system consists of the heart with a ventricle (v.) and two auricles (au.), the right auricle being bigger than the left, a single aorta, the anterior aorta, arteries and venous sinuses. The nervous system consists of a pair of widely separated and asymmetric cerebral ganglia, a pedal ganglion formed by the fusion of paired, pedal ganglia and a single parieto-splanchnic ganglion, from which nerves lead to different parts of the body. The

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Fig. 19. A. *Placenta placenta* (Linnaeus). B. *Placenta placenta* Anatomy with the left mantle and distal half of left gill having been removed. (after Hornell, 1909c). ad., adductor muscle; an f., anal funnel; a.o., aorta; au., auricle; f., foot; gl., gills; mt., mantle; neph., nephridia; l.p., labial palps; int., intestine; v., ventricle. C. *Modiolus tulipa* (Lamarck). D. *Modiolus undulatus* (Dunker). E. *Cardita bicolor* Lamarck. F. *Cardium assimile* Reeve. G. *Cerithium trailli* Sowerby. H. *Cymbium melo* (Solander). I. *Umbonium vestiarium* (Linnaeus). J. *Conus amadis* Gmelin.

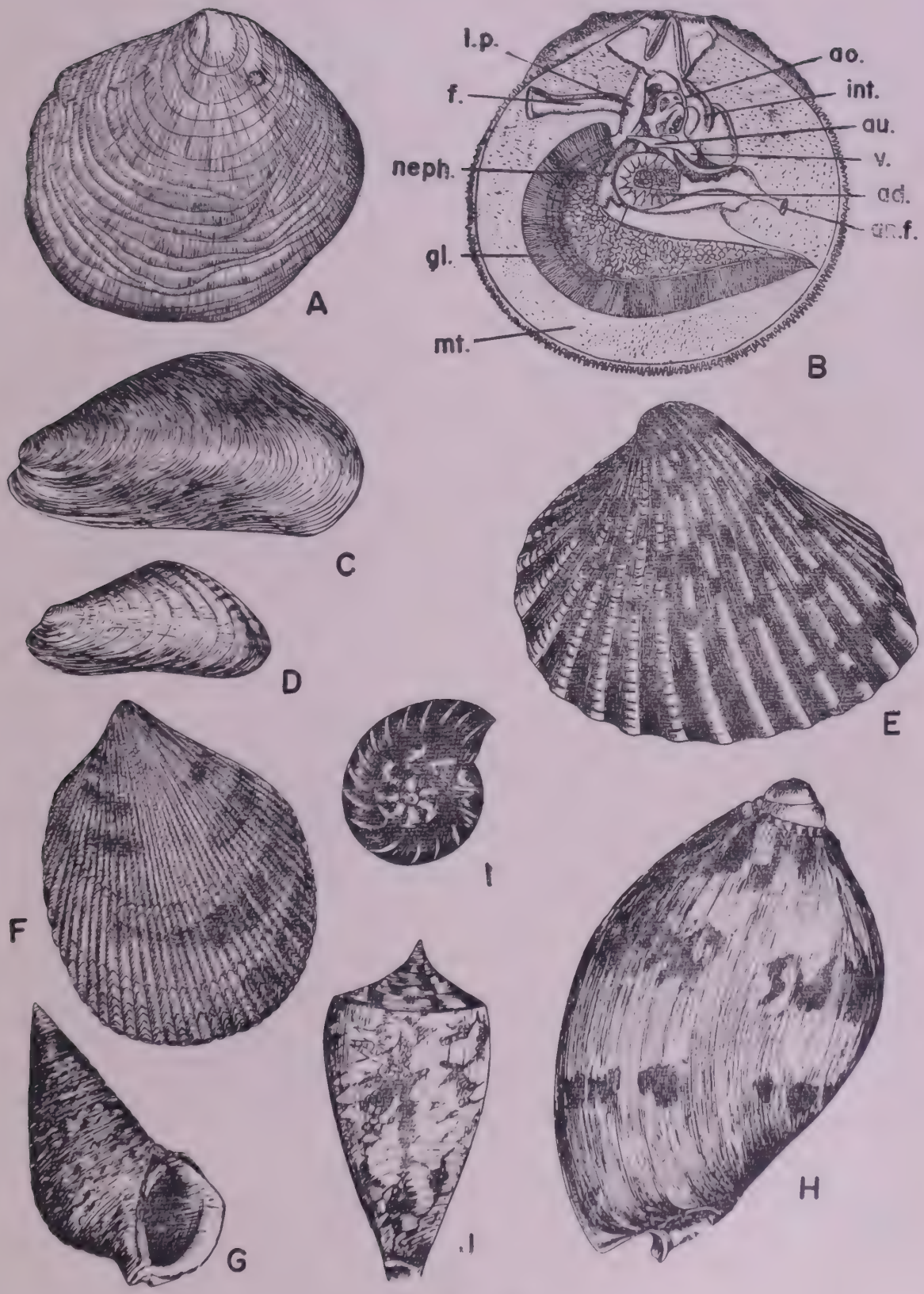

Fig. 19

excretory system is composed of a pair of asymmetric nephridia (neph.) which are connected dorsally by a short, transverse channel; the right nephridium has a long caecum posteriorly while the left one has only a short caecum. The nephridia open separately to the exterior at the ventral extremity of each renal tube near the parietosplanchnic ganglion. The gonad of the left side is suppressed and that on the right side is a highly irregular mass composed of a large lobe covering the stomach, digestive gland and coil of the intestine and a number of other lobes spread out in various directions in the right mantle. The gonad opens into the internephridial passage by a small aperture. Sexes are separate.

Distribution

In the Indian sub-continent it occurs in the Gulf of Kutch in Balapur Bay and Harbour and Rann Bay in Okha district, Bombay harbour and its neighbourhood, Malabar coast, Tuticorin, Buckingham Canal, Pulicat Lake, Korangi Bay (Andhra Pradesh), Ennore (near Madras), Nagapatnam, Mandapam area Karachi Harbour and numerous creeks of Sind coast. Shells of dead oysters are washed ashore at Pamban, Kundugal point and Athankarai Estuary (near Mandapam). Outside India, in Ceylon the window pane oysters are found in Tampalakam Lake, Sambore River and backwaters, Nilaveli, Deft Island and Palk Bay; the species is also well represented in Indonesia, Philippines, Cochin China, Southern China and Mergui archipelago.

Habits

The window-pane oysters inhabit muddy bottom of bays and creeks which are more or less land-locked. Usually the habitat is subjected to wide changes in salinity due to the opening of streams or rivers into them. The species can tolerate large variations in salinity. The oysters usually lie on their convex left valve. Observations made off Nagapatnam and Periapar off west coast of Ceylon (Hornell, 1909a) show that the species is capable of surviving at depths of six to seven fathoms.

Reproduction

The reproductive cycles and breeding periodicity have not been studied. Hornell (1909b) has stated that the species appears to spawn at the onset of the north-east monsoon in October. He opines that the fall in the specific gravity of the water in October following rains acts as a stimulus for spawning to take place.

Growth

Growth also has not been studied. Hornell (*loc. cit.*) has observed young oysters 15 mm in diameter in Rann Bay in Okha district in January and considered that they are about three months old.

Young oysters

The shells of young oysters up to about one year age are almost transparent with the soft parts seen through the shells. When the oysters grow further the shells are thicker and usually become white and translucent. Some of the young oysters possess pale pink bands radiating from the hinge while the shells of a few are suffused with pale pink colouration. But most of the young oysters are colourless.

Parasites and Pests

Larval cestodes and trematodes parasitize the window-pane oysters and lie encysted in the mantle edges. Fishes are infected when they attack the oysters and ingest fragments of the mantle with the parasites. The parasites become sexually mature in the vertebrate host. The polychaetes *Polydora* and *Eunice indica* have been recorded on the surface of window-pane oysters. The crab *Pinnotheres placunae* with a body highly compressed dorsoventrally is common in the mantle cavity of window-pane oysters in Okha and is a commensal of the oysters (Hornell and Southwell, 1909). *Pinnotheres placunae* has been recorded in window–pane oysters of Mandapam area also.

Fishery

Although *Placenta placenta* is widely distributed on the Indian coasts only in Balapur Bay and Rann Bay in the Gulf of Kutch it occurs in large quantities from the low tide mark to one and half fathoms. The window-pane oysters are fished in the Gulf by skin-diving. High rentals were got for the window-pane oyster fisheries of the Gulf of Kutch about 1914 but in recent times the fishery has declined. Hornell (1909a) has made some suggestions for the conservation of the window-pane oysters of the area viz., 1. teaching boys of the area swimming and diving 2. keeping watch for large beds of mature oysters and then attempt to lease them to a contractor. 3. stipulating that oysters below 11·4 cm (4½ inches) in length should not be fished. 4. oysters below this size should be relaid with the convex side downwards in the fishing ground if captured, 5. the lease of the beds should be given for a term of three or five years rather than for one year since in the former case the lessee will have more interest in the prosperity of the fishery and overcome loss incurred in a bad season. Window-pane oysters are found on Jamnagar coast, Thana creek in Bombay, and Korangi Bay in Andhra Pradesh in appreciable numbers and are fished.

Utilization

The thin, flat, iridescent shells of the window-pane oysters are used for glazing windows and doors. The shells are also used as decorative pieces in gardens (Rai, 1932). Pearls are formed by mature oysters. The pearls are not

of good quality as they are small and irregular in shape. They lack hardness and have poor lustre. They were used by Chinese in making medicinal preparations for diseases of eye and other ailments. In Ceylon the pearls are used in making a costly kind of slaked lime for applying on betel leaves for chewing. The meat of the window-pane oysters is not eaten in our country but is edible. When window-pane oyster shells are washed ashore in stray numbers they are used along with other molluscan shells in manufacturing lime. In Philippines extremely fine lamp shades and lamp stands are made out of this shell.

WEAVING MUSSELS: MODIOLUS SPP.

Many species of mussels belonging to the genus *Modiolus* occur in the Indian coasts, estuaries and brackish waters. The mussels are known as weaving mussels as they attach themselves to substratum by means of thin byssus threads. There is disagreement in regard to the indentity of some of the species (*vide* Annandale and Kemp, 1916). *Modiolus tulipa, M. metcalfei, M. perfragilis, M. trailli, M. undulatus, M. striatulus* and *M. barbatus* are well-known species of the Indian region. *M. auriculatus* (Krauss) has been recorded from the Madras harbour by Gravely (1941). *M. tulipa, M. undulatus* and *M. striatulus* occur in good quantities in some areas and are of commercial value. *M. tulipa* could be used for food by man (Hornell, 1951). All the three species could be utilized as poultry feed and fertilizer.

MODIOLUS TULIPA (Lamarck)

Shell moderately thick, outer surface traversed by concentric striae, there is a prominent oblique keel running from the umbo to the posterior side, the lower margin of the shell is slightly concave in the middle, the outer surface of the shell is glossy and yellowish brown in colour, the portion below the keel is usually marked off from the rest of the surface as a broad conspicuous, radiately widening whitish band. On the inner surface of the shell the upper half is purplish and demarcated from the lower half which is bluish white by an oblique line passing from the umbo to the posterior lower corner of the shell (Fig 19 C).

The mussels grow to a size of 7 cm. in length and are abundant in Palk Bay forming dense beds (Hornell, 1951).

MODIOLUS UNDULATUS (Dunker)

Shell thin, semi-transparent, upper margin strongly elevated at or near the middle and is sometimes subangulate, lower margin of shell straight or slightly concave, one of the two valves is slightly more inflated in some specimens. There are transversely striated costae in front of and below the umbo. Similar costae are present on the posterior edge of some of the shells and also sometimes

along its whole length. Preston (1914) has recognized mussels with the last mentioned type of ornamentation as var. *crassicostata*. The shell is yellowish green in colour with zig-zag purple lines which run transversely and are frequently interrupted and there are finer straight radiating lines of the same colour. Lines of both kinds frequently disappear almost completely on the lower half of the shell and the longitudinal ones are sometimes well developed in the posterior half. In some rare cases the entire surface with the exception of the extreme margin is suffused with purple pigmentation (Fig. 19 D).

These mussels have been reported by Annandale and Kemp (1916) on *Potamegaton* algae or submerged structures like ropes of fishing traps. The present author recorded the species in abundance as epifauna on *Crassostrea madrasensis* in Athankarai estuary. The mussels have been found to grow very rapidly and attain a maximum size of 11·4 mm in the estuary. Hundreds of spat of the mussel settled and grew on tiles dropped in the estuary for catching oyster spat. The mussels are to some extent harmful to the oysters as they colonise almost every available piece of hard substratum to the disadvantage of oyster spat. It is possible to obtain large quantities of this weaving mussel for being used as poultry feed and fertilizer by laying cheap cultch like old tiles in large numbers in sites where good spatfall is known to take place. The writer found that dried meat of this mussel is readily eaten by domestic fowls, when fed along with wheat flour or cooked rice.

Modiolus striatulus (Hanley)

After carefully studying shells of species recognised by previous workers Annandale and Kemp (1916) have included a number of nominal species viz., *M. jenkinsi* Preston, *M. cochinensis* Preston, *M. taprobanensis* Preston, *M. emarginata* Benson and *M. celator* Preston under *M. striatula*. This step is acceptable in view of the extreme variability of the shell characteristics of specimens from the same locality which show similarity to characteristics of specimens from other localities which have been recognized as different species.

Shell opaque, upper margin elevated and evenly arched, height of shell low, ventral margin concave or emarginate and in some it is almost straight, posterior margin rounded, radial ridges usually well developed. Colouration very variable. The colours are diffuse and dull, zigzag transverse purple lines and longitudinal striae may be detectable but the purple is not bright red and the ground colour is blue green. Fully developed shells are almost uniformly dull brown in colour. The species has been reported from Philippines, Gulf of Siam, Singapore, Ceylon, Burma and India. It is extremely abundant in Chilka Lake. It is represented also in the Gangetic delta, Calcutta docks, Bombay, Madras harbour and backwaters, Cochin backwaters and Pudumadam near Mandapam. At Pudumadam the species has been recorded by the present author, attached to rocks or branches of *Sargassum wightii* and is common in some seasons of the year.

Modiolus barbatus (Linnaeus)

Hornell (1951) states that *Modiolus barbatus* (Linn.) called *suran* by Tamil divers is very abundant in the Palk Bay and pearl banks of the Gulf of Mannar and several square miles of the sea bottom is covered with these bivalves. He says this mussel is a serious enemy of the pearl oyster as the two species have identical feeding habits and the rapidly multiplying *M. barbatus* has a blighting effect on the pearl oysters. Standen and Leicester (1909) have also recorded the mussel in the Palk Bay and Gulf of Mannar. The above authors have not given a description of this species.

In *Modiolus metcalfei* (Hanley) the shell is thin, anterior margin bluntly angular and rounded, dorsal margin angular in the middle, there is a keel running from umbo to posteroventral margin and the surface is covered with a fine brownish hairy periostracum. The shell of *M. perfragilis* (Dunker) is narrow, elongated and thin with anterior margin narrowed and obtusely angular and posterior margin broader and rounded. In *M. trailli* (Reeve) the shell is fairly thick, umbo almost terminal in position, anterior margin inclined, dorsal and ventral margins almost straight and the valves are markedly inflated posteriorly (Satyamurthi, 1956). The three species occur at Pamban and its neighbourhood.

Molluscs used in manufacturing lime

The molluscan shells used in making lime in India are predominently those of edible oysters (*C. madrasensis, C. gryphoides, C. cucullata* and *C. discoidea*) and clams especially *Meretrix* spp. Empty shells in large quantities are collected from the inshore areas at low tide and from the sub-fossil deposits lying below the ground surface which are several feet in thickness. There are rich sub-fossil molluscan shell deposits in the neighbourhood of Pulicat Lake, Surla in Orissa and Vembanad Lake in Kerala. On the Maharashtra coast huge amounts of oyster and clam shells are gathered in the southern creeks and backwaters and sent to Bombay after meeting local demand for conversion into lime. The lime is made by burning the shells in kilns constructed with brick and mortar or mud with bamboo supporting structures inside the walls. Molluscan shells of several species other than oysters and clams are suitable for preparing lime viz., *Mytilus* spp., *Cardita bicolor* (Fig. 19 E), *Cardium* spp. (Fig. 19 F), *Placenta placenta, Oliva* spp. (Fig. 20 G), *Cerithium* spp. (*C. trailli*, (Fig. 19 G), *C. clypeomorus, C. morus*), *Cerithidea fluviatilis*, *Conus* spp. (Fig. 19 J), *Murex* spp. etc. The lime is used for preparing mortar and for whitewashing buildings. Some quantities of molluscan shells are also used in the manufacture of cement.

Molluscan shells of value as curios

Shells of a number of species of molluscs belonging to the classes Pelecypoda, Gastropoda and Cephalopoda are cleaned, polished and sold as curios.

In this respect the gastropod shells rank first fetching good prices. The Melon shell *Melo indica* and *Turbo marmoratus* are large, beautiful shells which are treasured as mantel pieces and table decoratives. The shell of adult *Cymbium melo* (Solander) (Family Volutidae) which grows to 20 cm in height is almost globular in shape and pale reddish brown blotched with darker spots in natural condition and handsome with lustrous orange red colour when polished (Fig. 19 H). The melon shells live at depths of five to six fathoms in muddy sand in Palk Bay (Hornell, 1951). An interesting feature of this gastropod is that the eggs are deposited in a large egg mass of the shape of pine-apple and the parent carries the egg mass till the young ones leave it. The melon shells are carved and polished and table lamps made with its bright shell as lamp shade. A large *Cymbium* shell costs as much as Rs. 6 or 8. *Turbo marmoratus* possesses a large thick shell which is iridescent (Fig. 4 D) when the periostracum is removed by keeping the shell in water containing a little Hydrochloric acid. This shell which is common and fished in large numbers in Andaman Islands costs Rs. 15.

The five fingered chank *Lambis lambis* Linnaeus, the scorpion shell *Lambis chiragra* Linnaeus (Fig. 20 A), the sacred chank *Xancus pyrum* Linnaeus and the tun-shell *Tonna dolium* Linnaeus (Fig. 20 B) are other important large ornamental molluscs. *Lambis lambis* (Fig. 4 G) is found on east and west coasts and is very common in shallows in Palk Bay where there is good growth of algae. *Lambis chiragra* is common in the Laccadive Islands. The tun shells which have got their name due to their light, fragile shells (tun means light in Burmese) drift to the shore on the Indian coasts. They are also got in trawl catches in Mandapam area.

The cowries are shells of good commercial value. Several species of cowries are found on our coasts. The important species are the money cowry *Cypraea moneta* (Fig. 20 D), eye-cowry *C. ocellata*, black cowry *C. mauritiana*, tiger cowry *C. tigris* (Fig. 20 C), the Arabian cowry *C. arabica* (Fig. 20 E) and the serpents' head cowry *C. caput-serpentis* (Fig. 20 F).

The cowries inhabit rocky areas especially on and in the vicinity of coral reefs. They are common in Laccadive Islands. Many species are represented in the Gulf of Mannar and Bombay coast.

The money cowry *C. moneta* is common on reefs near Pamban. This cowry is purchased in dozens by people in India for dice-playing. The money cowries which were once employed in place of small money are used as ornaments in chains by tribal people and as an amulet (Hornell, 1951). The tiger-cowry *C. tigris* covered with large brown spots and the black cowry *C. mauritiana* with streaks and spots are beautiful, glossy shells that are used for interior decoration on tables and shelves.

Shells like olives (*Oliva gibbosa* and *O. nebulosa*), *Strombus canarium*, *Cerithium* spp., *Umbonium vestiarium*, (Fig. 19 I), *Arca* spp. (Fig. 20 H), *Cardita*

Fig. 20

bicolor, Dentalium spp. etc. are made into toys and dolls as figures of birds, human beings etc. by gluing the shells together. The figures so made are sometimes also painted. There is demand for such curios in cities, towns and coastal pilgrim centres.

Some utility articles are also made from some gastropod shells. By boring an opening at the top of the spire of the chank *Xancus*, baby milk feeders and blowing conches are made. Ash trays are made by mounting shells of *Xancus*, *Trochus niloticus* and *Murex virgineus* (Fig. 20 I) on wooden bases. Rings made out of shells of *Strombus canarium* are worn on fingers by some people in Tamil Nadu and in chains in Malabar and Kanara. Pearl buttons are manufactured from the thick and glossy mother-of-pearl of *Trochus niloticus* and *Turbo marmoratus*. The beautiful shells of *Nautilus pompilius* (Fig. 20 J) are thrown ashore on Indian coasts in the monsoon period. These shells are discoidal, coiled and divided by concave septa with a number of chambers. The inner part of the shell is pearly and the outer layer is porcellanous and pigmented with irregular, wavy, reddish brown bands on a whitish background. The shells which attain a size of 10–12·5 cm in diameter are ornamental molluscs.

At the present time decorative molluscan shells are fished and traded mainly by a small number of whole-sale agencies who sell them to the retail merchants. In the outer corridors of Sri Ramanatha Temple in Rameswaram there are a number of shops where beautiful ornamental molluscan shells and fancy articles like table-lamps, ash-trays and dolls made with shells are sold. Large quantities of shells of various species such as *Cypraea* spp., *Cassius rufus* etc. are also imported from Ceylon and Africa. There is good scope for the shell-craft industry to establish itself as a profitable industry if attempts are made to locate areas of abundance of different species, if fishing is done without causing large-scale destruction of stocks and last but not the least important if attempts are made to rear and culture some of the more common species.

Fig. 20. A. *Lambis chiragra* Linnaeus. B. *Tonna dolium* (Linnaeus). C. *Cypraea tigris* Linnaeus. D. *Cypraea moneta* Linnaeus. E. *Cypraea arabica* Linnaeus. F. *Cypraea caput-serpentis* Linnaeus. G. *Oliva nebulosa* Lamarck. H. *Arca inaequivalvis* Bruguiere. I. *Murex virgineus* (Roding). J. *Nautilus pompilius* Linnaeus.

X GENERAL CONSIDERATIONS

R. V. Nair

The foregoing chapters show that India is rich in commercial marine molluscan resources belonging to diverse species, the more important among them being the mussels, oysters, clams, squids, cuttlefish, the pearl-oyster *Pinctada fucata* and the sacred chank *Xancus pyrum*. Other resources like the ark-shell *Anadara granosa*, *Pinna bicolor*, the window-pane oyster *Placenta placenta*, edible gastropods and ornamental molluscs like *Turbo marmoratus*, *Trochus niloticus* and *Lambis lambis* exist in fair quantities in certain areas and are of some commercial value. However, the molluscan production of the country at present is much restricted. This is due to the lack of adequate interest in the available resources.

One immediate requirement in regard to the molluscan resources of the country is the conducting of a survey to assess their extent of availability. Survey of the cultivable edible molluscan shell-fish should be given priority as this will help in deciding the extent of fishing of the shell-fish that could be allowed, the prospects for culturing the different shell-fish and undertaking farming practices.

As a result of work done so far, we have a good knowledge of the identity of a number of commercially important clams, oysters, mussels, gastropods and cephalopods. Biological aspects of some of these shell-fish such as growth, reproductive cycles, spawning periods and habits as also their fisheries have been studied. In the places where the biology of the species has been investigated in detail experimental culturing of the species as some of the clams, oysters and mussels should be attempted. It is essential to farm edible bivalves as complete dependence on natural stocks as it is the case now will result in their decline within a very short time. Due to this reason in western countries and also in some eastern countries such as Japan and Malaysia mussels, oysters, clams and other bivalves are cultured in hundreds of farms to meet the large demand that exists.

The fact that beds of the green and brown mussels on the south-west coast of India are not as dense as in previous times suggests that there may be overfishing. Culturing of the mussels should be tried. As stated by Davies (1969, 1970) mussel culture should be highly profitable in India as Indian mussels attain sexual maturity very early and grow rapidly to marketable size. Through intensive mussel farming Holland and Spain have greatly increased their production and they produce together 1.996 million tonnes (F. A. O., 1970a) which is 62% of the

world mussel production. The British as well as the French 'buchot' methods should be tried in India and the one which is comparatively more profitable could be employed. Modifications have to be made to suit local conditions. The biology of *M. viridis* and the brown mussel should be investigated on the south-west coast as this information is necessary for culturing the mussels in the area.

Four species of oysters are available in large quantities on the Indian coasts viz., *Crassostrea madrasensis*, *C. gryphoides*, *C. cucullata* and *C. discoidea*. The biology of the first two species has been studied in detail and some information is available on the third species. The culture of these four species should be attempted in farms set up in the backwaters and estuaries*. The oyster species thrive well in brackish waters which are subject to inflow of freshwater to some extent. However, too much flooding of freshwater is injurious to the oysters and should be avoided. Oysters are capable of growing well even on muddy substratum if it is fairly hard. Loose muddy substratum could be hardened by adding sand, pebbles and shells and allowing them to settle Environments with too much of algal growth or where there is settlement of mussels like *Modiolus* spp. and areas where there is shifting sand or mud should be avoided as oyster populations will not flourish there. The different methods of oyster culture practised in other countries like raft method, rack method, 'long-line' method and stick method should be adopted and it should be determined which methods are efficient.

Experimental culture of mussels and oysters should be preceded by studies to determine areas where ripe and spawning individuals of the species are available in large numbers; studies on induced spawning and determination of the hydrological conditions under which maturation, spawning, setting, growth and fattening take place should be undertaken. It is also necessary to understand what may be the favourite food items of the bivalves.

Meretrix casta, *M. meretrix*, *M. meretrix ovum*, *Gafrarium tumidum*, *Tapes pinguis*, *Villorita cyprinoides*, *Katelysia opima* and *Donax* spp. are the chief species of clams of commercial importance. There is better demand for clams than for oysters especially on the west coast. The harvests from the natural beds can be supplemented by farming the clams In Bombay seed clams are collected and planted in tidal flats with a hard surface and sold after about a year when they reach marketable size. But clam culture in the true sense of the term is not done in India. For clam culture seed clams should be available

*Recently oyster spat have been collected by Dr. K. Satyanarayana Rao on oyster shell cultch and reared to marketable size of 105 mm in nine months in Athankarai Estuary near Mandapam Camp. Mussels have been successfully cultured by Mr. G. P. Kumaraswami Achari at Vizhinjam using rope culture method and the mussels attained an average size of 70 mm.

in plenty. These should be planted in the density which will result in rapid growth. The farm area should be hardened as it promotes growth. The soil should be treated periodically in order to check acidity which is unfavourable to clams.

Edible bivalves should not be cultured in environments in which sewage is drained as the bivalves being filter feeding naimals will imbibe and harbour disease-producing bacteria. As the habitat of bivalves is usually polluted the shell-fish have to be cleaned before consumption. If they are kept for some days in fresh unpolluted sea water they will be rendered harmless. In a method developed at Conway mussels are first washed with fresh water, then kept in tanks containing sterilized sea water to which chloride of lime has been added one day and in sterilized sea water alone on the second day and finally washed with chlorinated water, packed in sterilized bags and sent to markets. Some toxins are developed occasionally in clams, oysters and mussels following feeding on the dinoflagellate *Gonyaulax*. The presence of the toxins should be detected by bioassay and bivalves containing more than safe limits of toxins should not be consumed.

There is very little demand for edible gastropods in India. On the other hand in western countries these are fished and consumed in large quantities. If edible gastropods could be harvested in fair quantities on our coasts they could be processed, canned and exported.

The cephalopods are fished in appreciable quantities in India, the production being 1,515 tonnes in 1968 and 769 tonnes in 1969. The important species are *Sepia rouxii, S. aculeata, S. rostrata, Sepiella inermis, Sepioteuthis arctipinnis, Loligo duvauceli, L. hardwickii, Octopus rugosus, O. octopodia* and *O. favonia*. The cephalopod catches are got only incidentally in shore-seines, boat seines and trawl nets operated for fin-fishes. The resources of the offshore waters are practically not exploited. Studies conducted recently (Silas, 1969) have shown that a number of species such as *Symplectoteuthis oulaniensis, Sepia aculeata, S. pharonis, Sepiella inermis* and *Loligo duvauceli* are available in the off-shore waters of west coast. Systematic exploratory fishing should be carried out on the continental shelf and beyond to locate new grounds both in the Bay of Bengal and in the Arabian Sea. The method of jigging used in other countries for fishing squids and cuttlefish should be employed by our fishermen also. Mechanised jigging done by the Japanese (Aldrich, 1969) is especially efficient as a number of units could be operated simultaneously from the fishing vessel.

One unfortunate fact is that most of the people of our country do not know of the nutritive value of molluscan shell-fish or avoid them with prejudice due to having never eaten them before. The Central Government and the maritime states of our country should through extension schemes popularize

the molluscan shell-fish pointing out the nourishing qualities of these sea foods rich in protein, glycogen, fat, vitamins and several minerals. If the edible molluscan production is increased through culture practices and intensive fishing, the shell-fish could be canned using modern methods and exported to other countries after meeting internal demand as mentioned by Rao (1969).

The pearl oyster resources in the Gulf of Mannar off Tuticorin coast comprising mainly of *Pinctada fucata* have been exploited from very remote times and famous for high quality pearls they yield. A maximum revenue of Rs. 8,65,000 was realized by the Madras Government in 1959 from the pearl fishery conducted in that year and a revenue of Rs. 3,18,000 in 1961 when the last fishery was conducted. There have been only thirtyeight fisheries during the last three centuries (Chacko, 1970). This is due to the fact that pearl oyster populations exhibit wide fluctuations in their density. The periodical decline in the populations is influenced by several factors among which failure of spatfall, pests like weaving mussels and boring worms, overgrowth of algae, predation by octopi, sharks, rays and sea-breams (*Lethrinus* spp.), are predominant factors. A detailed study of the ecology of the pearl banks in the Gulf of Mannar and the estimation of pearl oyster populations has been taken up for investigation by the Central Marine Fisheries Research Institute and some results of the studies have been published (Mahadevan and Nagappan Nayar, 1967). The only way of exploiting the pearl oyster resources to best advantage is to farm the pearl oysters and evolve a method of producing spherical culture pearls. The Indian pearl oyster *Pinctada fucata* (Gould) is suitable for pearl culture as the nacreous layer of the pearl oysters is fairly thick and highly iridescent. India can save valuable foreign exchange if pearl culture is done in the country. We are importing at present large quantities of culture pearls worth millions of Rupees, from Japan (Alagarswami, 1970). To accomplish pearl culture successfully some problems like the absence of calm bays and the occurrence of blooms of *Noctiluca* have to be overcome. Preliminary work conducted by the Madras Fisheries Department (Devanesan and Chacko, 1958) shows that it is possible to rear pearl oysters if proper care is taken of the oysters. Through adequate and careful research work it is possible to develop methods of farming the Indian pearl oyster and inducing it to produce perfectly spherical culture pearls of high quality.*

The sacred chank *Xancus pyrum* which is adored and used in worship by Hindus and also in the manufacture of shell bangles supports an important fishery on the Tirunelveli and Ramanathapuram coasts. The environmental

* Culture pearls have been obtained by Dr. K. Alagarswami about three months after introducing nuclei in *Pinctada fucata* and rearing the operated pearl oysters in cages suspended from a raft off Veppalodai near Tuticorin.

conditions, biology, habits and density of populations of the sacred chank of Tuticorin area where the richest chank grounds are located are being studied in detail by the Central Marine Fisheries Research Institute using SCUBA equipment for the first time (Mahadevan and Nagappan Nayar, 1966). The studies have shown that chanks are not restricted to areas of moderate depths as was considered previsously but occur at depths up to 27 metres. It has been suggested that chanks may be present at depths greater than this. The deeper areas have not been investigated due to limitations of diving equipment. Attempts are being made to locate new chank grounds so that production could be increased.

Several species of ornamental molluscs such as the window-pane oysters, *Turbo marmoratus, Lambis chiragra, Lambis lambis, Cymbium melo, Cypraea* spp., and *Oliva* spp. with beautiful shells inhabit the coastal waters of India, including Andaman and Laccadive Islands. We have only a vague idea about their distribution and abundance in a few areas where they are found to be common. The magnitude of the resources should be assessed in the different parts of our coastline and attempts should be made to exploit them without causing undue destruction of the stocks. As stated by Rao (1969) the shell-craft industry has much scope in India since it is possible to export the products to other countries like U.S.A. which import large quantities of these from Japan. Within the country also the demand for ornamental shells may be expected to increase in cities and major towns in future as people may come to appreciate the beautiful shells and utility articles made with them if attempts are made to carve and polish shells and present them in an attractive manner.

To exploit the molluscan resources of our country properly as it is done in several advanced countries a thorough grasp of knowledge on the extent of the resources, their biology and ways in which the resources have to be exploited should be acquired. The governments of the maritime states of the country should regulate fishing by maintaining closed seasons, fixing minimum size in the case of individual species below which the species should not be fished and enforcing legal measures for contravention of the regulations. If necessary efforts are made, the molluscan production of India could be increased several times the present figure and we can export canned molluscan sea foods.

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Errata

Page	*Line*	*For*	*Read as*
7	26	*M. viriais*	*M. viridis*
8	Last line	hem	them
11	23	3.8 cm diameter	3.8 cm in diameter
11	36	Italy	and Italy
12	10	cocoanut	coconut
13	14	Anisomyria	Anisomyaria
15	2	glosssy	glossy
18	4	males	male
19	1	Biochenical	Biochemical
19	24	Adayar	Adyar
23	21	*Navicula–Ceratium*	*Navicula, Ceratium*
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26	4	C_a0	Ca 0
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41	9	cost	coast
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48	27	*D, cuneatus*	*D. cuneatus*
49	9	MESODERMA	MESODESMA
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56		Author's name at top	K. S. SUNDARAM
58	22	argae	algae
62	29	optium	optimum
65	3	*S aculeata*	*S. aculeata*
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113	13	bivalves	molluscs
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116	19	*P. chemnitzi*	*P. chemnitzii*
116	38	few	a few
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126	11	Karagadu	Karangadu
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